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BULLETIN
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INTERNATIONAL RAILWAY CONGRESS
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(ENGLISH EDITION)

[656. 222.1]

Note on Train Speeds,

by LIONEL WIENER,
Professor at the University of Brussels.

PART II *(Continued).* (1)

Train speeds and services in different countries.

IX. — SWITZERLAND *(concluded).*

CHAPTER XXXVIII.

The train speeds.

XXXVIII-1. — **General.** — Before considering the Swiss train speeds, we propose to give some information about the way the services are divided up between steam traction, electric traction, and railcars.

There are in addition — especially in Switzerland — other methods of transport which should be dealt with, together with their speeds : rack or cable railways, as well as navigation on the lakes, which carry an important amount of traffic. These will be dealt with in an appendix.

XXXVIII-2. — **Electric traction.** — Owing to lack of coal, an abundance of water resources, and the mountainous nature of the country, Switzerland has electrified (up to the end of December, 1933) 3 720 km. (2 311.5 miles) of line, 2 113 km. (1 313 miles) of which are operated by the *Swiss Federal Railways*, out of their total kilometrage of 2 943 km. (1 828.8 miles) using 15 000-volt 16 2/3-cycle monophase current. There would be no point in giving the complete list of these lines; it is, indeed, much simpler to mention the principal lines whereon steam traction is still used.

— STANDARD-GAUGE STEAM RAILWAYS.

Geneva-La Plaine.	Wald-Rüti-Rapperswil.
Auvernier-Verrières (Pontarlier).	Uznach-Ziegelbrucke.
Délémont-Delle.	Bülach-Winterthur.
Délémont-Basle.	Schaffhausen-Konstanz-Romanshorn.
(Berne) Gümligen-Lucerne.	Rorschach-Buchs.
Stein-Coblence-Eglisau.	

(1) Cf. *Bulletin of the Railway Congress*, October and November 1933; May, June and July 1934; February, March, April, May and July 1935.

With the exception of the (Berne) Gümligen-Lucerne and (Zurich) Wallenstein-Rapperswil lines, these are all frontier lines.

The metre like the standard-gauge lines, are generally electrified; there are 1 301 km. (808.4 miles) of electrified lines, while only 341 km. (211.9 miles) are still worked by steam (beginning of 1934).

Apart from the Rhône Valley and a few other railways in the north-eastern part of the country, most lines are too hilly for high overall speeds.

Yet the overall speed of the Lötschberg and especially the St. Gothard trains is remarkable, as it is as much as 65 km. (40.4 miles) an hour over 1 in 37 gradients. So as to achieve this, it has been estimated that 22 to 25 tons adhesive weight is required per 100 tons hauled; as the express trains often weigh up to 600 tons, some 150 to 160 tons adhesive weight was needed. With 20-ton axle loads, this was obtained by using coupled electric locomotives, each with four pairs of driving wheels.

The I-B-I-B-I + I-B-I-B-I locomotives weighing 245 t. (241 Engl. tons) in working order, with 160 to 172 t. (157.4 to 169.2 Engl. tons) adhesive weight — probably the most powerful engines in the world (1) — can haul up 1 in 37 gradients :

600 t. at 62 km. (590 Engl. tons at 38.5 miles) an hour (passenger trains);

750 t. at 50 km. (738 Engl. tons at 31 miles) an hour (goods trains split into two sections).

The maximum speed is 100 km. (62 miles) an hour on the level. When fitted with electric brakes, they can slow down from 65 to 5 km. (40.4 to 3.1 miles) an hour on 1 in 37 gradients, in 2 minutes i.e. within a distance of 1 000 metres (1 093 yards).

Level-line 4-8-2 (1928) type locomotives used between Olten and Basle and between Olten and Zurich weigh 117.5 t. (115.6 Engl. t.) and have 80 t. (78.7 Engl. t.) adhesive weight.

The first Swiss electric standard gauge line was the *Berthoud (Burgdorf) Thun Ry.* (1899), equipped on the three-phase system at 750 volts, 40 cycles. The original motor cars and locomotives had two speeds only : 18 and 36 km. (11.2 and 22.4 miles) an hour; those built between 1910 and 1918 had four, ranging from 14 to 44 km. (8.7 to 27.3 miles) an hour.

In spite of this improvement and the line's economical operation, the Company changed over to the *Swiss Federal Rys.* standard (15 000 volts, single-phase 16 2/3-cycle) current, when it electrified further sections of its own system.

XXXVIII-3. — **Electric motor coaches, and rail motor cars.** — So as to speed up certain services or to replace trains that did not pay their way, the *Swiss Federal Railways* have used vehicles of the above types, although the rapid electrification of the system has restricted them to relatively few services.

On the other hand, motor cars with or without trailers radiating around important places are being run to frequent standardised schedules. Various classes of motor coaches are used.

Electric motor coaches. — We quote

(1) Starting effort measured at the shaft of the engine : (60 000 kgr. = 132 280 lb.).

Hourly tractive effort, hourly rating . . .	38 300 kgr. (84 437 lb.) (speed 62 km. = 38.5 miles an hour).
Hourly power	8 800 H.P.
Continuous power	8 300 H.P. (65 km. = 40.4 miles an hour).

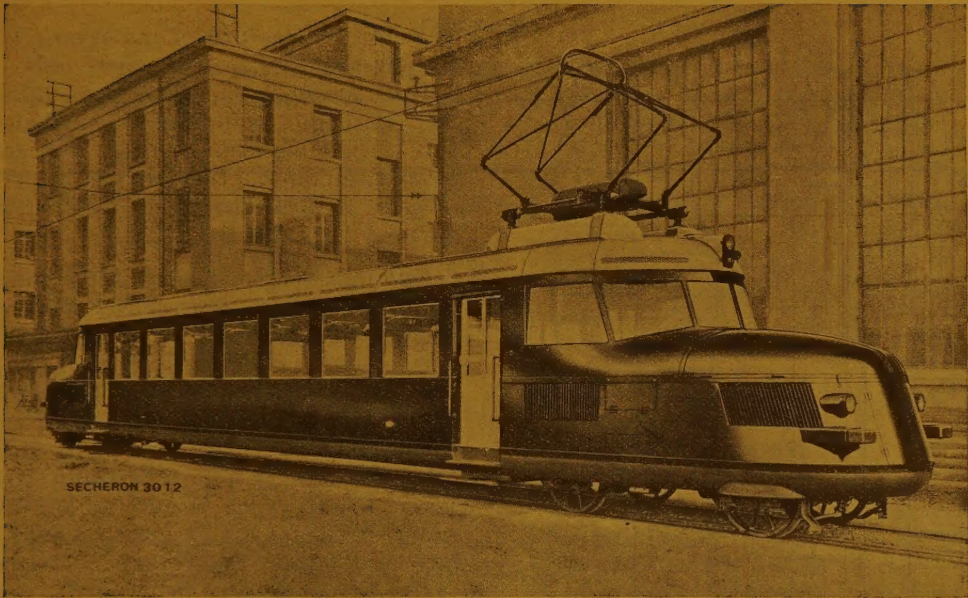


Fig. 232. — Swiss Federal Rys. new fast electric motor coach.

hereafter, the leading dimensions of recent electric cars, amongst which an electric motor van by Messrs. Sécheron (for the electric portion) and the Schlieren Works (for the mechanical).

The rakes comprise three groups of three third-class articulated vehicles containing 333 seats, besides a double-bogie second-class 54-seater trailer, which brings the total length up to 114 m. (374 feet) and the weight, motor van included, up to 230 t. (226.3 Engl. tons). It can be driven from either end.

The 64 t. (63 Engl. tons) motor van meets the following conditions as regards speed and hauling capacity.

Tons.		Gradient.	Speed.	
Metric.	Engl.		Km./h.	M. p. h.
		on the level.	85	52.8
170	167.3	1 in 200	58	36.0
170	167.3	1 in 100	50	31.0
50	49.2	1 in 38	50	31.0

The *Bodensee-Toggenburg Ry.*'s electric coaches have a maximum speed of 80 km. (50 miles) an hour. The *B.L.S.*'s are similar to the *B. N.*'s and can attain a speed of 90 km. (56 miles) an hour.

FAST ELECTRIC COACHES. — The *Swiss Federal Railways* have recently ordered, to the same general dimensions, two different types of express coaches, with a maximum speed of 125 km. (77.7 miles)

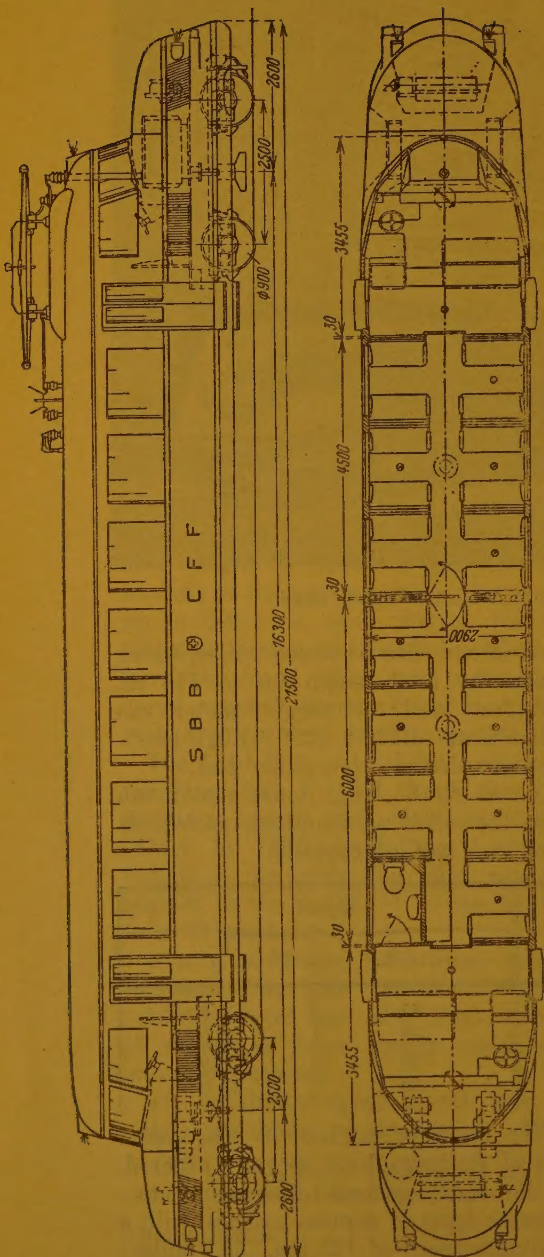


Fig. 232*a*. — Swiss Federal Railways, new electric motor coach.

an hour, whereas that of the electric locomotives is 100 km. (62 miles) only.

Their weight is about 31.5 t., of which the electrical equipment contributes 11.5 t. Like the diesel vehicles, they are partly streamlined. They can seat 52 passengers, or 70 if the tip-up seats fitted are used (figs. 232 and 232*a*).

Railcars. — The diesels of the same class as the *Swiss Federal Rys.* electric coaches will weigh 29.5 t. (29.0 Engl. tons) only i.e. 0.420 t. (0.413 Engl. ton) per seat, this being slightly less than the corresponding weight of the electric motor units (1). They are to be used between Soleure-Morat-Palézieux and Vevey, a line which is still worked by steam, except for the 7.8 km. (4.8 miles) between Chexbres and Vevey.

The *Val de Travers Regional Ry.* was one of the first (in 1923), to run Winterthur-built diesel cars, similar to the Saxon diesels. The line is 11 km. (6.83 miles) long. These vehicles proved satisfactory and the *Swiss Federal Rys.* ordered similar cars in 1928, but with 250-H.P. eight-cylinder engines; they weighed 57 t. (56.1 Engl. tons) and hauled 68 t. (66.9 Engl. tons). In 1929, a 420-H.P. diesel van of the same weight was added to the stock.

This stock was used over the 30-km. (18.6 miles) section from Berne to Langnau of the Lucerne line, which took 54 minutes, including 5 stops, to work over. It has been transferred elsewhere, the line having just been electrified.

The *Bodensee-Toggenburgbahn* (2)

(1) The continuous brake horse-power of the 6-cylinder 1 450-r. p. m. Sulzer engine is 290 during one hour, or 320 for half an hour.

(2) Romanshorn (alt. 1 318 ft.) . . 0 km.
Degersheim (alt. 2 630 ft.) . . 37 km. (23 miles).
Wattwil (alt. 2 024 ft.) . . . 53 km. (32.9 miles).

TABLE 218.

LEADING DIMENSIONS OF SWISS ELECTRIC MOTOR COACHES.

COMPANY.	B. L. S.	S. F. Rys.	S. F. Rys.	Bodensee-Toggenburg.	S. F. Rys.
Type of vehicle	3rd cl.	3rd cl.	Van.	2nd-3rd.	Electric or diesel.
Length, overall	21.90 m. (71′ 10 7/16″)	20.00 m. (65′ 7 3/8″)	15.20 m. (49′ 10 7/16″)	20.60 m. (67′ 7″)	21.50 m. (70′ 6 15/32″)
Body, length	19.70 m. (64′ 7 19/32″)	...	...	...	...
Do. width	3.00 m. (9′ 10 1/8″)	...	2.90 m. (9′ 6 19/32″)	...	2.90 m. (9′ 6 19/32″)
Outside height	3.50 m. (11′ 5 25/32″)	...	...	...	3.35 m. (11′ 1/8″)
Bogie wheelbase	3.30 m. (10′ 10″) 2.70 m. (8′ 10 23/32″)	3.20 m. (10′ 6″) 3.20 m. (10′ 6″)	2.50 m. (8′ 2 7/16″) 2.50 m. (8′ 2 7/16″)	2.90 m. (9′ 6 19/32″) 2.75 m. (9′ 9/32″)	2.50 m. (8′ 2 7/16″) 2.50 m. (8′ 2 7/16″)
Distance between bogie centres	13.60 m. (44′ 7 7/16″)	12.80 m. (42′)	8.80 m. (28′ 15/32″)	13.75 m. (45′ 1 25/32″)	16.30 m. (53′ 6″)
Wheels, diameter	1.04 m. (3′ 4″) 0.85 m. (2′ 9 1/2″)	1.04 m. (3′ 4″) 0.85 m. (2′ 9 1/2″)	1.04 m. (3′ 4″) 1.04 m. (3′ 4″)	1.04 m. (3′ 4″) 1.04 m. (3′ 4″)	0.90 m. (2′ 11 1/2″) 0.90 m. (2′ 11 1/2″)
Weight in service	...	86 t. (84.6 Engl. t.)	64 t. (63.0 Engl. t.)	63.5 t. (62.5 Engl. t.)	31.5 t. (31.0 Engl. t.)
Do. empty	74 t. (72.8 Engl. t.)	79 t. (77.7 Engl. t.)	...	57.7 t. (56.8 Engl. t.)	...
Number of seats	90 + 30 standing.	...	...	16 + 50	70 + 20 standing
Weight, per passenger	0.617 t. (0.607 Engl. t.)	...	...	0.962 t. (0.947 Engl. t.)	...

operated by the *Swiss Federal Railways* also owns second- and third-class rail-cars supplied by the Winterthur Works in 1930. They weigh, with a seating capacity of 66, 36 t. (35.4 Engl. tons), i.e. 0.545 t. (0.536 Engl. ton) per seat.

These railcars haul (their own weight included) :

200 t. at 40 km. (196.8 Engl. tons at 25 miles) an hour on the level.

125 t. at 25 km. (123 Engl. tons at 15.5 miles) an hour up 1 in 100 gradients.

70 t. at 25 km. (68.9 Engl. tons at 15.5 miles) an hour up 1 in 50 gradients.

In 1929, the metre-gauge *Appenzel Railway* (26 km. = 16.2 miles from Appenzel to Gossau) also substituted 250-H.P. diesels to its steam-hauled trains. Later — in 1933 — the diesels also have been withdrawn, the line having been electrified and operated with three-car trains [1]. The maximum speed of 50 km. (31 miles) an hour has remained unchanged.

---

(1) Direct current at 1 500 to 1 600 volts is used. The motor units have four 165-H.P. nose-supported motors.

TABLE 219.

NOTEWORTHY SWISS RUNS.

RUN.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Number of stops.	Speed. Km./h	Speed. Miles/h.	
Standard gauge.								
Basle-Zurich-Enge Buchs	196	122	3.48 a. m.	2.52	2	68.4	42 8	Arlberg.
Basle-Zurich H. B.-Coire	205	127	7.17 a. m.	3.19	3	61 8	38.4	Netherlands.
Basle-Zurich-Enge	92	57	12.00 noon	1.17	...	71.7	44.5	Do.
Zurich-Enge-Sargans	88	55	5.05 a. m.	1.16	...	73.3	45.6	Arlberg Express.
Zurich-Enge-Coire	118	73	8.43 a. m.	1.59	...	59 5	37.0	
Basle-Zurich	88	55	1.06 p. m.	1.11	...	74.3	46.2	
Zurich H. B.-Ragaz	98	61	R 7.39 p. m.	1.30	...	65.4	40.5	Netherlands.
Do. -Ziegelbrücke	57	35	4.24 p. m.	0.50	...	68.4	42.5	
Do. -Sargans	92	57	11.12 p. m.	1.19	...	68.7	42.6	
Zurich Schaffhausen	47	29	7.09 a. m.	0.45	...	62.7	38.9	
(Zurich) Frauenfeld-Weinfelden	17	11	10.04 a. m.	0.13	...	78.5	48.8	
(Zurich) Winterthur-Wil	27	17	7.50 a. m.	0.23	...	70.5	43.8	
Wil-St. Gallen	30	19	12.05 a. m.	0.24	...	75.0	46.6	
Basle-Lucerne	94	58	6.45 a. m.	1.23	...	68.0	42.2	Paris.
Basle-Olten	39	24	6.45 a. m.	0 34	...	69.4	43.1	Do.
Olten-Lucerne	55	34	7 21 a. m.	0.47	...	70.2	43.6	Do.
(Basle) Lucerne-Chiasso	225	140	8.18 a. m.	4.02	6	55.5	34.4	
	...	...	R 6.12 p. m.	3.52	3	57.5	35.7	Calais.
Lucerne-Bellinzona	170	106	*7.05 a. m.*	*3.16*	...	*51.9*	*32.3*	In 1914.
Lucerne-Arth-Goldau	28	17	8.18 a. m.	0.27	. .	62.2	38.6	Paris.
Arth-Goldau-Göschenen	61	38	8.55 a. m.	1.01	...	60.0	37.3	
Do. -Airolo	77	48	R 2.53 a. m.	1.13	...	63.3	39.3	
Do. -Bellinzona	142	88	R 7.17 p. m.	2.16	...	62.6	38.9	
Göschenen-Bellinzona	80	50	10.00 a. m.	1.13	...	65.7	40.8	
Airolo - Do.	65	40	1.44 a. m	1.07	...	58.4	36.0	
Bellinzona-Lugano	29	18	R 6.43 p. m.	0.30	...	58.0	36.0	
Lugano-Chiasso	26	16	11.55 a. m.	0.25	...	62.4	38.7	
Zurich-Arth-Goldau-Chiasso	241	149	R 6.12 p. m.	4.22	4	55.2	34.2	
Zurich-Olten-Berne (Geneva)	134	83	11.23 a. m.	2.00	2	67.0	41.6	Internal.
Berne-Olten	66	41	8.50 p. m.	0.55	...	72.0	44.7	
Aarau-Zurich	54	34	1.38 p. m.	0.45	...	72.0	44.7	
Delle Berne-Spiez-Interlaken	168	103	6.01 a. m.	4.05	6	41.2	25.6	Oberland Express.
Do. Do. -Brig	224	139	R 11.08 a. m.	4.33	10	49.2	30 5	Rome-Paris.
Berne-Thun	31	19	8.42 a. m.	0.25	...	74.4	46.2	Calais.
Thun-Spiez	11	7	12.27 p. m.	0.11	...	60.0	37.3	
Spiez-Frutigen	13	8	R 12.14 p. m.	0.14	...	55.6	37.9	
Frutigen-Kandersteg	18	11	12.03 p. m.	0.19	...	56.8	35.3	
Goppenstein-Brig	26	16	1.40 p. m.	0.25	...	62.4	38.7	
Spiez-Brig	74	46	*1.14 a. m.*	*1.24*	...	*52.9*	*32.9*	In 1914.
Geneva-Berne-Olten-Zurich	292	181	11.00 a. m.	4.57	7	59.0	36.7	Ventimiglia.
Geneva-Berne	157	98	11.00 a. m.	2.24	2	65.4	40.6	

TABLE 219 (*continued*).

NOTEWORTHY SWISS RUNS.

RUN.	Distance. Km.	Distance. Miles.	Time of departure.	Time spent.	Number of stops.	Speed. Km./h.	Speed. Miles/h.	
Standard gauge.								
ıeva-Berne-Olten-Basle	263	164	11.00 a. m.	4.32	5	58.0	36.0	
·eneva-Lausanne	60	37	7.45 a. m.	0.45	...	80.0	49.7	Internal.
Do. -Renens	56	35	R 7.32 p. m.	0.44	..	76.3	49.1	
ɹausanne-Fribourg	66	41	11.55 a. m.	0.60	...	66 0	41.0	
ıeva-Lausanne-Bienne-Basle . . .	238	148	...	...	...	...	...	
)o. -Renens- Do. . . .	228	142	6.02 p. m.	3.27	7	66.1	41.0	
ɹausanne-Yverdon	38	24	5.33 a. m.	0.31	...	73.5	45.7	
'verdon-Neuchâtel	36	22	R 3.54 p. m.	0.30	...	72.0	44.7	
Jeuchâtel-Bienne	29	18	6.38 a. m.	0.25	...	69.6	43.3	
nne-Berne (Interlaken)	33	21	5.58 a. m.	0.31	...	63.9	39.7	
g-Lausanne-Geneva	206	123	8.46 p. m.	3.06	...	66.4	43.5	Paris.
)omodossola-Brig	40	25	7.35 p. m.	0 47	...	51.1	31.7	Do.
	...	...	R 9.23 a m.	0.40	. .	60.6	37.7	Do.
3rig-Sion	53	33	10.58 p. m.	0 41	...	77.6	48.2	Simplon Orient.
ion-Montreux	68	42	11.40 p. m	0.54	...	75.6	47.0	Do.
ıchâtel-Berne	43	27	R 2.14 p. m	0.45	2	57.3	35.6	Berne-Neuchâtel Co.
Metre gauge.								
re-Samaden-St. Moritz	89	55	R 8.00 p. m.	2.30	2	35.6	22.1	Engadine-Express.
Coire-Bevers	82	51	R 4.45 p. m.	2.15	...	36.4	22.7	(Rhätische Bahn).
oire) Landquart-Davos-Filisur . .	69	43	11.26 a. m.	2.14	5	30.9	19.2	
Landquart-Schiers	12	8	11.26 a. m.	0.17	...	43.3	26.9	
3rig-Viège	9	6	11.30 a. m.	0.15	...	36.0	22.4	Visp-Zermatt Bahn.
Moritz-Poschiavo-Tirano . . .	61	38	1.20 p. m.	2.36	5	18.9	11.8	Bernina Ry.
Pontresina-Poschiavo	38	24	1.26 p. m.	1.31	...	25.1	15.6	Do.
llinzona-Mesocco	31	19	10 30 a. m.	1.27	15	21.4	13.2	Company.
carno-Bignasco	27	17	R 3.46 p. m.	1.18	15	20.8	12.9	Do.
carno-Domodossola	53	33	R 3.26 p. m.	2.10	14	24.5	15.2	Do.
oleure) Biberist-Berne	30	19	1.46 p. m.	0.46	...	39.1	24.2	Do.
Montreux-Zweisimmen	62	39	*2.00* p. m.	*2.19*	...	*26.7*	*16.6*	M. B. O. in 1914.
	...	...	R 3.22 p. m.	2 14	7	27.7	17.2	Montreux-Berner Oberland.
Gstaad-Château d'Oex	13	8	3.56 p. m.	0.21	...	37.1	23.0	Do.
Aigle-Sépey-Diablerets	22	14	7.16	1.23	13	10.1	6.2	Do.

XXXVIII-4. — **Noteworthy Swiss runs** (fig. 233). — Table 219 shows both long-distance and sectional runs. Unless otherwise stated, all trains are electrically worked.

XXXVIII-5. — **Conclusions.** — Table 221 quotes the Swiss overall train speeds (fig. 233).

Fig. 233. — Map of Swiss railways, showing the maximum overall speed on each line.

Legend :

= 80 to 90 km. (50 to 55.9 miles) per hour.
= 70 to 79.9 km. (44 to 49.9 miles) per hour.
= 60 to 69.9 km. (37 to 43.9 miles) per hour.
= Less than 60 km. (37 miles) per hour.

TABLE 220.

THE FASTEST SWISS TRAINS.

RUN.	Distance. Km.	Distance. Miles.	Times of departure.	Time spent.	Speed. Km./h.	Speed. Miles/h.	—
Standard gauge.							
Geneva-Lausanne	60	37	7.45 a. m.	0.45	80.0	49.7	
Brig-Sion (Vallorbe)	53	33	10.58 p. m.	0.41	77.6	48.2	Simplon-Orient
Sion-Montreux (Vallorbe)	68	42	11.40 p. m.	0.54	75.6	47.0	Express.
(Winterthur) Wil-St. Gallen	30	19	12.05 a. m	0.24	75.0	46.6	
Basle-Zurich H. B.	88	55	R 1.06 p. m.	1.11	74.3	46.2	
Berne-Thun (Lötschberg)	31	19	8.42 a. m.	0.25	74.4	46.2	B. L. S. Co.
Lausanne-Yverdon (Bienne)	38	24	5.33 a. m.	0.31	73.5	45.7	
Zurich-Enge-Sargans	88	55	5.05 a. m.	1.16	73.3	45.6	
Berne-Olten *(Zurich)*	66	41	8.50 p. m.	0.55	72.0	44.7	
(Berne) Aarau-Brugg-Zurich	54	34	1.38 p. m.	0.45	72.0	44.7	
Basle-Zurich-Enge	92	57	12 00 noon	1.17	71.7	44.5	
(Zurich) Winterthur-Wil	27	17	7.50 a. m.	0.23	70.5	43.8	
(Zurich) Wil-Gossau (St. Gallen)	20	12	8.14 a. m.	0 17	70 5	43.8	
(Basle) Olten-Lucerne	55	34	7.21 a. m.	0.47	70.2	43.6	
Buchs-Ragaz	21	13	2.17 p. m.	0.18	70.0	43.5	
Basle-Olten (Lucerne)	39	24	6.45 a. m.	0.34	69.4	43.1	
Metre gauge.							
Lucerne-Giswil (Brienz)	29	18	8.18 a. m.	0.36	48.8	30.3	Brünig Bahn.
Brienz-Interlaken Ost.	17	11	R 4.30 p. m.	0.21	48.6	30.2	Do.
Landquart-Schiers	12	8	11.26 a. m.	0.17	43.3	26.9	Rhätische Bahn.
(Soleure) Biberist-Berne	30	19	1.46 a. m.	0.46	39.1	...	Zollikofen-Berne.
Gstaad-Château d'Oex	13	8	3.56 p. m.	0.21	37.1	23.0	M. B. O.
Château d'Oex-Montbovon	11	7	4.18 p m.	0.18	36 7	22.8	M. B. O.
Coire-Samaden	84	52	R 8.14 p m.	2.16	37.1	23.0	Rhätische Bahn. Engadine Exp.
Davos Platz-Filisur	19	12	1.09 p. m.	0.31	36.7	22.8	

TABLE 221.

MILEAGE OF LINES RUN OVER AT VARIOUS OVERALL SPEEDS.

ota .	S.F.R.	B.L.S. (1)	B.N. (2)	P.L.M.	BOD. (3)	OVERALL SPEED Miles/h.	OVERALL SPEED Km./h.	S.F.R.	B.L.S.	B.N.	P.L.M.	BOD.	Total.	Per cent.
	← Miles →							← Kilometres →						
...	...	...	...	...	...	Over 62	Over 100	...	...	...	...	...	...	...
...	...	...	...	...	...	56 to 61.9	90 to 99.9	...	...	...	...	...	...	...
38	38	...	..	...	...	50 to 55.9	80 to 89.9	61	...	...	...	...	61	2
473	473	..	...	...	...	44 to 49.9	70 to 79.9	761	...	...	...	...	761	22
737	637	53	19	9	19	37 to 43.9	60 to 69.9	1 025	85	30	15	31	1 186	36
823	721	69	8	3	22	Less than 37	Less than 60	1 160	111	13	4	36	1 324	40
071	1 869	122	27	12	41	← TOTAL →		3 007	196	43	19	67	3 332	100

(1) Berne-Lötschberg-Simplon.
(2) Berne-Neuchâtel (through).
(3) Bodensee-Toggenburg Bahn.

APPENDIX.

We give below, similar information to the above, concerning rack and cable railways, and Swiss lake boats and the speeds of these various services. It is possible to deduce therefrom whether it is advantageous to use such transport or to revert to simple-adhesion railways.

XXXVIII-6. — **Rack railways.** — We will not devote much space to pure rack railways, but will mention rack train speeds and weights, these being the chief factors affecting their capacity, as all of them are single-track lines.

With a view to increasing their output, the weight per seat has mainly engaged the attention of engineers, the locomotive tractive effort being increased and the car weight decreased (fig. 239). As these cars are always very light, the weight of the passengers represents a far larger proportion of the total weight than it does in other kinds of railways.

Whilst pure rack railways exist mainly for pleasure, this is not so with the mixed lines, on which the use of the rack section has made it possible to link up two places by a much shorter route than would have been possible with any simple-adhesion railway. By the end of 1933,

TABLE 222.

SPEED ON A FEW RACK RAILWAYS, STEAM OR ELECTRICALLY WORKED.
We have added certain other useful data.

LINE.	Altitude.		Rack.		Run.		Maximum overall speed.			—
	Upper end	Lower end	Length	Gradient	Time	Stops	—	Rack	Adhes.	
	Feet.	Feet.	Miles.	1 in	Hours.	No.	M. p. h.	M. p. h.	M. p. h.	
Electric traction.										
(Bex) Villars-Bretaye ..	...	...	5.8	...	0.30	...	...	...	...	...
Gornergrat	5 275	10 147	2.5	5	1.11	3	4.84	4.54	17.4	1898
Jungfrau	6 837	11 341	5.84	4	1.10	3	5.03	4.97 4.35 5.6	21.1 7.5 22.7	1898 ... 1912
Brunnen-Axenstein . .	1 476	2 323	1.24	...	0.16	1	4.66	...	...	...
Wengernalp	3 402-2 523-6 771		11.8	4	2.22	5	4.97	5.6	20.5	1909
Schynige Platte (2′ 7 1/2″ gauge)	1 926	6 463	4 5	4	0.52	1	5.2	5.25	21.1	1914
Schöllenenbahn . . .	3 628	4 721	2.3	...	0.23	...	5.97	...	...	...
Arth-Righi	1 690	5 741	5.5	5	1.04	3	5.03	...	..	...
(Vevey) Bonay-Pléiades .	1 266	4 432	2.9	5	0.54	4	4.0	..	...	...
Steam traction.										
Vitznau-Righi	1 447	5 741	4.2	4	1.02	5	4.2	. .	...	...
Brienz-Rothorn . . .	1 535	7 388	4.7	...	1.10	1	4.04	...	...	. .
Rochers de Naye (2′ 7 1/2″ gauge)	2 270	6 473	4.7	6	1.07	4	4.2	..	...	. .
Monte Generoso . . .	896	5 200	2.4	4.5	1.11	1	2.05	...	...	...
Pilatus	1 438	6 791	2.85	2	1.15	...	2.24	...	...	...

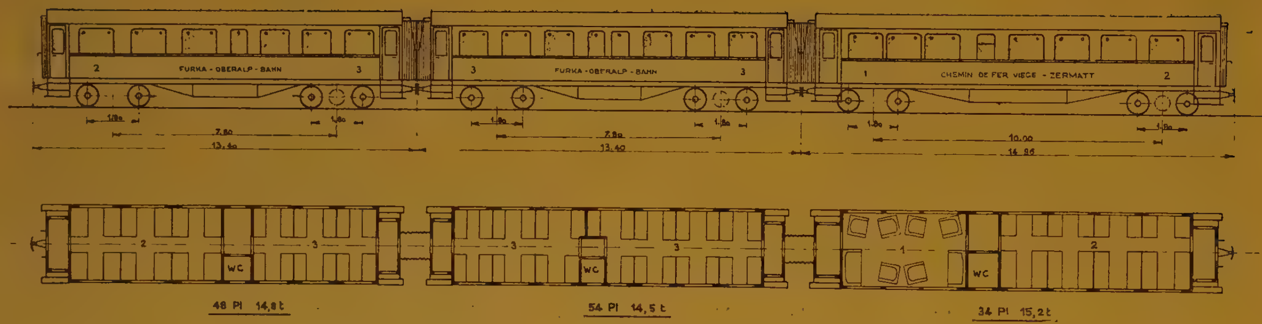


Fig. 234. — The Glacier Express. — Usual make-up of the train.

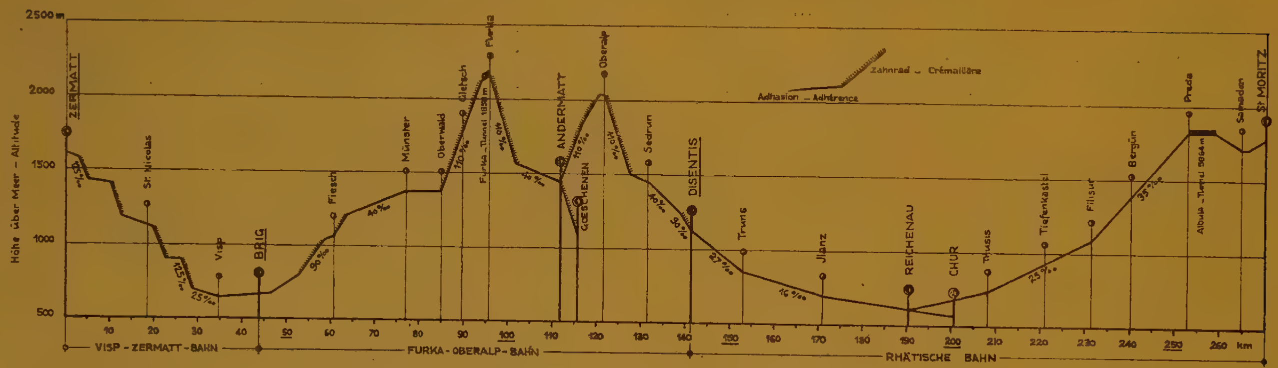


Fig. 235. — Gradient section of the Zermatt-St. Moritz line.
[(Brig)-Viège, Zermatt, Furka-Oberalp and Rhaetian Railway Cos.]

Table 223.

SWISS MIXED ADHESION AND RACK RAILWAY LINES.

MIXED LINE (and altitude of the end station when it is lower than the maximum shown in Column 2).	Altitudes		Length		Gradients		Run		Speed			Weight		Seats.
	Lower end.	Maximum.	Adhes.	Rack.	Adhes.	Rack.	Time.	Stops.	Overall.	Max. Adhes.	Max. Rack.	Locomotive or motor car.	Trailers.	
	Feet.	Feet.	Miles.	Miles.	1 in	1 in	Hours.	No.	M. p. h.	M. p. h.	M. p. h.	Engl. tons.	Engl. tons.	No.
Aigle-Leysin	1 316	4 757	3.85	2.99	40	4.3	1.00	5	3.85	...	3.7 to 7.4	7.4 adh. 12.3 rack. (1)	4.3 to 12.3	20 to 66
(Aigle) Monthey-Champéry	1 332	3 441	7.89	2.24	20	7.4	1.02	7	9.6	9.9 to 18.6	4.35 to 6.8	29.5	37.4 (train)	...
Bex-Chésières	1 348	4 002	8.64	3.03	17	5	0.50 1.19	4 8	3.7	...	4.35 to 7.4	17.7 or 19.7 mot. (2)	35.4 or 61.0 (train)	40
Martigny-Le Châtelard	1 335	3 671	11.68	1.57	14	5	1.33	7	7.5	15.5	4.35	37.4	75.7 (train)	...
Leuk-Leukerbad	2 041	4 606	6.34	2.78	20	6.2	1.06	5	6.3	12.4	5.0	...	...	...
Brig-Viège-Zermatt	2 204	5 275	27.34	4.62	50	8	1.55	1	21.9	27.9	12.4 to 8.7	47.2 loc.	59.0	...
Viège-Zermatt	2 136	5 275	21.75	4.62	...	...	0.35	...	13.7	...	..	...	...	...
Brig-Viège (adhes.)	2 204	2 136	5.59	...	40	8	0.16	...	21.1	...	...	...	...	...
Brig-Disentis (3 717 ft.)	2 204	7 100	60.27	19.71	25	9	4.36	5	13.2	25.0	12.4	*41.3 loc. serv.*	*59.0*	...
Brig-Fiesch	2 204	3 494	10.75	...	...	11	0.40	...	16.2	...	...	...	...	...
Fiesch-Gletsch	3 494	5 784	17.96	...	25	9	1.10	...	15.4	..	...	...	...	...
Gletsch-Andermatt (4 721 ft.)	5 784	7 100	13.55	...	25	9	1.05	...	12.5	...	...	...	...	...
Oberalpsee-Disentis	6 670	3 717	12.43	...	25	9	1.01	...	12.2	...	...	...	...	...
Interlaken-Grindelwald	1 860	3 402	12.06	2.70	40	8	1.05	5	10.1	12.4	6.2	35.4	157.5	...
Lucerne (Brunig)-Brienz (1 860 ft.)	1 430	3 287	45.92	5.61	40	8	2.27	5	19.2	...	...	32.5 loc.	275.5	800
Lucerne-Giswil	1 430	1 526	18.02	...	55	...	0.38	...	25.0	34.2	...	32.5 + 63.0	98.4	280
Giswil-Brunig	1 526	3 287	6.21	...	...	..	0.29	...	12.8	23.6	12.4	32.5	49.2	...
Brunig-Meiringen	3 287	1 952	3.73	...	...	...	0.20	...	11.2	23.6	9.3	...	...	...
Meiringen-Brienz-Interlaken	1 952	1 860	18.02	...	62	...	0.34	...	30.0	37.3	...	32.5	392	1150
Stansstad-Engelberg	1 437	3 287	13.98	0.93	40	4	1.03	4	13.9	7.1	3.4	12.3 (3)	29.5 (train)	...
Saint-Gall-Appenzell (2 589 ft.)	2 198	3 054	12.12	3.49	20.1	10.8	1.06	5	11.0	18.6	6.2	31.5	49.2 (train)	...
Rorschach-Heiden	1 207	2 605	3.85	3.39	..	11	0.33	3	7.0	9.3	5.0	23.6 serv.	...	...
Alstätten-Gais	1 411	3 012	5.72	2.07	19	6.2	0.38	7	9.2	18.6	6.2	9.8 (4)	33.5 to 41.3 55.1 (5)	...

(1) Maximum gradient of the simple adhesion section of the tramway: 1 in 10.2.
(2) 1900-1904.
(3) 1898-1912.
(4) 1911.
(5) 1914.

these mixed lines included 109 km. (67.7 miles) of rack sections.

Although this method is but little used in Europe, it has been widely applied elsewhere; it is therefore of interest to consider each instance separately.

On the *Viège-Zermatt Railway* (V. Z.), the substitution of electric traction for steam, which took place in 1929, made it possible to reduce the journey time from 2 h. 5 m. to 1 h. 35 m. The B-B locomotives have the following speeds :

On the level :

With simple adhesion	45 km. (28 miles) an hour.

On the rack section :

On gradients, 1 in 142	20 km. (12.4 miles) an hour.
1 in 142 to 1 in 9	18 to 15 km. (11.2 to 9.3 miles) an hour.
1 in 9 to 1 in 8.6	14 km. (8.7 miles) an hour.

The maximum weight of the trains is 108 t. (106.3 Engl. tons), including the 48-t. locomotive and three 44-t. carriages. Single-phase current at 11 000 volts, 16 2/3 cycles, is used, this being its first application to rack railway locomotives.

On the *Appenzell Railway*, where there are 1 in 17 gradients on the simple adhesion, and 1 in 11 on the rack sections, the speed is respectively 40 and 20 km. (25 and 12 1/2 miles) an hour, in spite of curves of as small a radius as 30 m. (1 1/2 chains), due to the fact that for 5 km. (3.1 miles) the railway is laid along a road. It would have been possible to construct a simple adhesion line instead of this mixed one but its length would have been 16 km. (10 miles) instead of 14 km. (8.7 miles), and it would have cost 3 500 000 francs instead of 1 900 000 to build.

On account of the gradients, the increases in the virtual length in force for luggage rates are as follows :

Jungfrau	9.4	km.	counted	as	240.
Brunnen	2.0	»	»	»	30.
Arth-Righi . . .	8.6	»	»	»	72.
Rochers de Naye .	7.6	»	»	»	80.
Les Pléiades . . .	4.7	»	»	»	48.

The running speed is 9 km. (5.6 miles) an hour up a 1 in 4 gradient. On the ordinary simple adhesion section the speed does not exceed 45 km. (28 miles) an hour up 1 in 40 gradients.

On the *Wengernalp Railway* the speed up 1 in 66 gradients is 8.5 km. (5.3 miles) an hour; beyond this it is 10 to 11 km. (6.2 to 6.8 miles). On Mount Pilatus (1) 480 mm./m. (1 in 2) gradient, it is 7.5 km. (4.7 miles) an hour.

The weight per passenger of the 6.3 t. (6.2 Engl. tons) vehicles with 40 seats is 158 kgr. (348 lb.) on the Wengernalp. On the Rothorn where, since the line was strengthened, the trains have comprised 2 carriages, a bogie vehicle and a 4-wheeled one, this weight is 81 and 72 kgr. (178.5 and 158.7 lb.) respectively, as the 3.9-ton and 2.3-ton carriages seat 48 and 32 passengers.

This information is obviously incomplete, as account must also be taken of the weight of the entire train including the locomotive.

On the Wengernalp, the maximum weight of a train is 48 t. (47.2 Engl. tons) on a 1 in 52 gradient and 38 t. (37.4 Engl. tons) on a 1 in 4 gradient.

(1) Steam railcar.

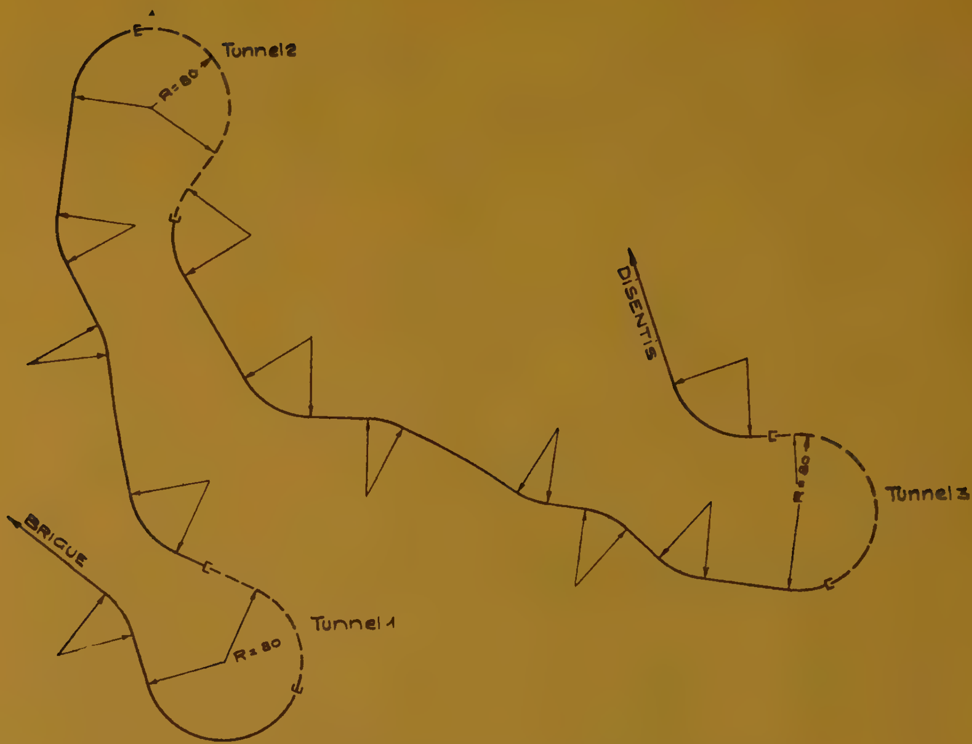


Fig. 236. — Double loop of the Furka-Oberalp Railway.

IMPORTANT TRAINS. — The « Glacier Express » which runs in turn over the *Viège-Zermatt Ry.* (44 km. = 27.3 miles), the *Furka-Oberalp Bahn* (97 km. = 60.3 miles from Brig to Disentis), and *Rhätische Bahn* (129 km. = 80.2 miles from Disentis to St. Moritz) is the most remarkable mixed line train, and its 270 km. (167.8 miles) run is the longest metre-gauge one in Europe. Starting at an altitude of 1 608 m. (5 275 feet) at Zermatt, it runs down to 651 m. (2 136 feet) at Viège, and climbs peaks 2 164 and 2 033 m. (7 100 and 6 670 feet) high before running down again to 607 m. (1 994 feet) into Reichenau after which it ends the run at St. Moritz at 1 778 m. (5 803 feet) above sea level.

The *Viège-Zermatt Railway* runs from the Rhône Valley to a famous alpine health resort (1). A simple adhesion line between the same places would have been 35 885 m. (22.3 miles) long.

The line has been extended 9 km. (5.6 miles) up the Rhône Valley so as to reach Brig, whence starts the *Furka-Oberalp Bahn*, which, since the 18th October 1926, has been connected at Di-

(1) The *Gornergrat Railway*, which in parts is 3 093 m. (10 147 feet) above see level.

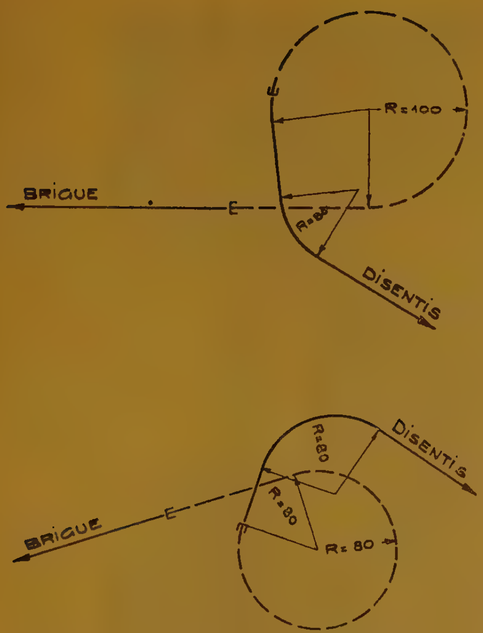


Fig. 237. — Spiral (helicoidal) tunnels of the Furka-Oberalp Railway.

sentis, via the St. Gothard, with the *Rhätische Bahn*. Gradients, 1 in 25 on the simple-adhesion section become as steep as 1 in 16 to in 1 in 9 on the rack railway, and the running speed of the locomotives (1) is 40 and 20 km. (25 and 12 1/2 miles) an hour respectively. To conquer the abrupt changes in altitude of the district it was needful not only to use rack sections, but also to bore a number of tunnels, one of which on a 1 in 32 gradient, under the Furka Pass, is 1 832 m. (1.14 miles) long; another is a 548-m. (0.34 mile) spiral tunnel and three double loops carry the line up the Oberalp (fig. 236).

There are but few rail connections between this railway and other Swiss lines. Apart from rail connections at both ends, two others only have been decided upon. The first of them, which so far, is in the projected stage only, is to run from Gletsch (on the *Furka-Oberalp* line), via the Grimsel, to Meiringen whence it is possible, to continue either to Lucerne or to Interlaken over the *Brünig Ry.*'s metre-gauge metals. The second one, already in operation, in a small rack railway which runs from Andermatt (1 444 m. = 4 606 feet altitude) down to the portal of the St. Gothard tunnel (2).

Rolling stock runs indiscriminately over all three railways, one of which only, the *Rhätische Bahn*, is a simple-adhesion one, besides having to run, in the near future, over the pure rack *Schöllenenbahn* as well. It is therefore fitted with cogged wheels for braking and a triple system of lighting, for the lighting system used on the two end railways differs, while the middle one is not electrified. In spite of this, the stock is very light, although it runs at speeds of as much as 45 km. (28 miles) an hour. The weight of the most recent bogie carriages with intercommunication vestibules, steel buffers, and heating pipes is only 300 kgr. (660 lb.) per seat. This result has been achieved by the use of cast steel for the frame and of anticorodal whose specific weight is only 2.70. The weight per passenger, of the old four-wheeled stock,

(1) These 2-6-0-T steam locomotives weigh 34 t. (33.5 Engl. tons) empty, and 42 (41.3 Engl. tons) in working order.

(2) The *Schöllenenbahn* is operated by the *Viège-Zermatt Ry. Co.* as an integral part of the *Furka-Oberalp Ry.* It is 3.7 km. (2.3 miles) long, the maximum gradients are 1 in 59. Unlike on the *Furka-Oberalp*, electric traction is used.

Fig. 238. — Viège-Zermatt metre-gauge Railway.
Carriage built by the Neuhausen Works.

was some two thirds that of the modern bogie stock.

At the present time, the « Glacier Express » is made up of three vehicles which run from end to end (fig. 237) : a third class carriage, a *Furka-Oberalp* composite 2nd and 3rd, and a *Viège-Zermatt* composite 1st and 2nd (fig. 238), besides a rack van. A *Mitropa (Rhätische Bahn)* restaurant car is added at Disentis.

The *Brünig Bahn* (metre gauge), is one of the earliest of mixed railways. Racks are only used to climb over the pass and this is the only part of the railway where virtual kilometric rates apply.

The 0-6-0-T adhesion locomotives, weighing 28.9 t. (28.4 Engl. tons). 33 t. = 32.5 Engl. tons, in working order, haul :

400 t. (394 Engl. tons) up 1 in 62 gradients, and

280 t. (276 Engl. tons) up 1 in 55 to 1 in 45 gradients.

The rack locomotives weigh 28.2 t. (27.5 Engl. tons) [32 t. = 31.5 Engl. tons, in working order]. Their maximum load is 50 t. (49.2 Engl. tons), or 100 t. (98.4 Engl. tons) with two additional rack pushers.

Their maximum speed up 1 in 8 gradients is 20 km. (12 1/2 miles) an hour, and 15 km. (9.3 miles) down them. On

1 in 9 gradients, the speed is . .	16 km. (9.9 miles) an hour.
On 1 in 10, it is	17 km. (10.6 miles) an hour.
On 1 in 11, and less	18 km. (11.2 miles) an hour.

On the line's adhesion sections, the speed is 38 km. (23.6 miles) an hour.

XXXVIII-7. — Cable railways. - There are still, in Switzerland, a number of water-operated cable railways, whose capacity has been considerably increased latterly.

THE LAUSANNE INCLINED PLANES. — These standard-gauge planes, which connect with the main lines, carry both passengers and goods; they differ completely from all other Swiss railways.

Originally built between Ouchy and Lausanne only, a second track has been laid between the *Federal Rys.* Lausanne station, which is located half way up, along the upper section as far as the Town of Lausanne. These lines are the only ones worked by hydraulic turbines with big drum winches. They are also the only Swiss standard-gauge cable railways, all others, save the Neuveville (1.20 m. = 3 ft. 11 1/4 in. gauge) Rheineck, St. Gall and Marzili-Berne lines (0.75 m. = 2 ft. 5 1/2 in. gauge), having been laid to metre gauge.

The *Lausanne Cable Railway* is not a steep one (1 in 40 to 1 in 7.6 only). On the Ouchy line, the speed reaches 4.40 m. (14.4 feet) per second (about 15 km. = 9.3 miles an hour) with 3 car-trains, each of the cars seating 40 to 50 passengers; on the Lausanne Town (upper) line, the single 40-seater carriage pushes a loaded goods wagon up before it.

Amongst the OTHER LINES, the longest section is the *Stanserhorn IInd* (1 990 m. = 1.24 miles); the entire railway line, divided into three sections, is 4 812 m. (3 miles) long and climbs up 1 475 m. (4 840 feet).

The single-section *Schwyz-Stoos Cable Railway*, whose gradients reach 1 in 13 is the steepest of the Swiss cable railways. On its short run, it climbs up 702 m. (2 300 feet).

TABLE 224

LEADING DIMENSIONS OF RECENT ROLLING STOCK, VIÈGE-ZERMATT AND FURKA-OBERALP RAILWAYS.

CLASS OF CARRIAGE / WHEN BUILT.	3rd, 1890	2nd, 1907	1st, 2nd, 3rd, 1934	1st, 2nd.	2nd, 3rd.	3rd.
Company	V. Z.	V. Z.	V. Z.	V. Z.	Furka.	Furka.
Length, overall	14.95 m. (49′ 19/32″)	14.90 m. (48′ 11″)	14.90 m. (48′ 11″)	14.96 m. (49′ 1″)	13.40 m. (43′ 11 9/16″)	13.40 m. (43′ 11 9/16″)
Body length (including two 2′ 5 1/2″ vestibules) . .	8.60 m. (28′ 2 5/8″)	14.00 m. (45′ 11 3/16″)	14.00 m. (45′ 11 3/16″)	14.00 m. (45′ 11 3/16″)	12.50 m. (41′ 1/8″)	12.50 m. (41′ 1/8″)
Body width	2.70 m. (8′ 10 5/16″)	2.60 m. (8′ 6 11/32″)	2.60 m. (8′ 6 11/32″)	2.60 m. (8′ 6 11/32″)	2.70 m. (8′ 10 5/16″)	2.70 m. (8′ 10 5/16″)
Outside height	3.10 m. (10′ 2″)	3.29 m. (10′ 9 9/16″)	3.29 m. 10′ 9 9/16″)	3.35 m. (10′ 11 29/32″)	3.30 m. (10′ 10″)	3.30 m. (10′ 10″)
Bogie wheelbase	4.30 m. (14′ 1 5/16″)	1.40 m. (4′ 7 1/8″)	1.40 m. (4′ 7 1/8″)	1.70 m. (5′ 7″)	1.80 m. (5′ 11 7/8″)	1.80 m. (5′ 11 7/8″)
Distance between bogie centres	(2 axles only)	10.00 m. (32′ 9 3/4″)	10.00 m. (32′ 9 3/4″)	10.00 m. (32′ 9 3/4″)	7.80 m. (25′ 7″)	7.80 m. (25′ 7″)
Wheel diameter	0.70 m. (2′ 3 1/2″)	0.70 m. (2′ 3 1/2″)	0.70 m. (2′ 3 1/2″)	0.70 m. (2′ 3 1/2″)	0.70 m. (2′ 3 1/2″)	0.70 m. (2′ 3 1/2″)
Seats, number	40	42	44	24 + 10	48	54
Tare weight	7.5 t. (7.3 Engl. t.)	12.7 t. (12.5 Engl. t.)	13 t. (12.8 Engl. t.)	15.2 t. (15.0 Engl. t.)	14.8 t. (14.6 Engl. t.)	14.5 t. (14.3 Engl. t.)
Weight per seat	0.187 t. (0.184 Engl. t.)	0.302 t. (0.297 Engl. t.)	0.295 t. (0.290 Engl. t.)	0.441 t. (0.433 Engl. t.)	0.308 t. (0.303 Engl. t.)	270 t. (0.266 Engl. t.)

The capacity of the Swiss cable railways varies from the 16 to 20 seats of the small *Fürigen Ry.*s car, built by Theodor Bell in 1923, near the Lake of Lucerne, to the 70-80 seats of the *Chantarella Ry.* (near St. Moritz) and the *Zugerberg Ry.* carriages, which these railways were able to put into service after their lines had been modernised by the same builder, in 1930-1931.

The speed of the trains has been considerably increased in recent years; it has often been doubled, sometimes even trebled :

3 m. (9.8 feet) per second (10.8 km. = 6.7 miles an hour) is the speed, since 1931, of the *Zugerberg Cable Ry.*, with 70-85 seat carriages, on gradients as steep as 1 in 2.1.

3.20 m. (10.5 feet) per second (11.5 km = 7.14 miles an hour) on the new *Chantarella-Corviglia* cable sections (1928) with 1 in 22 gradients and carriages containing 50-60 seats, and on the *Davos Cable Ry.*

3.40 m. (11.2 feet) per second (12.2 km. = 7.6 miles an hour) on the *Cossonay* cable, water worked, railway, rebuilt in 1929, with 50-seat carriages, and with maximum 1 in 7.8 gradients.

Fig. 239. — Recent carriage built by the Schlieren Works for the *Gornergrat Railway*.

The *San Salvatore* line, rebuilt by Bell in 1925-1926, runs 70-seat carriages at 2 m. (6.56 feet) per second [1] whereas previously 35-seat carriages ran at a speed of 1.25 m. (3.9 feet) only per second.

Thanks to the new quick acting brakes the vehicles can be brought to a dead stop on a distance of 2.82 m. (9.2 feet), when running down a 1 in 1.8 gradient, fully loaded, at a speed of 5.68 m. (18.7 feet) a second. At a speed of 2 m. (6.56 feet) a second, it stops in 0.56 m. (1.83 feet).

The same builder increased the speed on the *Braunwald* (Glaris) *Cable Railway* from 1.20 m. (3.94 feet) to 2.25 m. (7.38 feet). The *Mount Pelerin* (Vevey) *Cable Ry.* was also altered to that the speed could be increased to 3.00 m. instead of 1.50 m. (9.84 instead of 4.92 feet).

(1) The four independent wheels of each carriage had to be replaced by four bogies with 2 wheels running on the same rail, and placed like the wheels of telpher lines, one behind the other.

Even on heavier gradients, the speeds are still remarkable :

1 in 1.28 : 2.05 m. (6.72′) per sec., i.e. 7.4 km. (4. 6 miles) an hour.
Schwys Stoos . . . . 50 seats.

1 in 1.66 : 2.00 m. (6.56′) per sec., i.e. 7.2 km. (4.47 miles) an hour.
San Salvatore . . 60 to 70 seats.

XXXVIII-8. — **Navigation on the lakes.** — Regular boat services are maintained on 15 of the Swiss lakes, which are situated at an altitude of 400 to 600 m. (1 300 to 1 970 feet) above sea level. Only two of these on the Italian frontier are at a lower altitude, and a couple of lakes in the Haute-Engadine are much higher, at some 1 800 m. (5 900 feet) above datum.

When the lakes are of a very irregular shape, the length of the water route may be very different from the distance between the two ends. The distance varies, for example, on the Lake of Lugano from 41 km. (25.5 miles) (median distance) to 21 km. (13 miles), as the crow flies, and in the case of the Lake of Geneva, from 72 to 90 km. (44.7 to 55.9 miles) according to which shore is followed.

Three of the lakes are crossed up by DYKES OR JETTIES : the Lake of Lugano at Melide (816 m. = 2 677 feet long), the Lake of Zurich at Rapperswil (951 m. = 3 054 feet), and the Lake of Constance. All these dykes are followed by railway lines.

Only on the Lake of Constance are VIRTUAL TARIFF DISTANCES applied. The journey from Constance to Schaffhausen is increased in this way by 3 km. (1.86 miles).

The speed of the express boats is 25 km. (15.5 miles) an hour on the Lakes of Geneva and Lugano. The speed of the other boats is slightly lower :

23 km. (14.3 miles) an hour on the Lake of Thun,

21 to 22 km. (13.0 to 13.7 miles) an hour on the Lake of Brienz,

22 to 24 km. (13.7 to 14.9 miles) an hour on the Lakes of Zurich and Geneva,

19 to 20 km. (11.8 to 12.4 miles) an hour on the Lake of Lugano.

On the Lake of Lucerne it varies from 20 to 30 km. (12.4 to 18.6 miles).

On the canals and along the shores the speed is lower in order to avoid causing a wash. It is 13 km. (8.1 miles) on the Thun and Interlaken canals, 14 (8.7 miles) on the Aar canal, and 22 (13.7 miles) on the Rhine, between Stein and Schaffhausen.

The running speed of the motor boats on the Lake of Thun is 16 km. (9.9 miles) an hour, and on the Lake of Zurich, 18 km. (11.2 miles).

One minute (Lake of Zurich) to two minutes (Lakes of Thun, Brienz, and Constance), is allowed for each stop, and one to three minutes on the Lake of Geneva, while another minute is allowed for arrival and starting.

LAKES AND RIVERS. — Some of the boat services on the lakes are completed by river services. Thus the boats proceed from the Lake of Neuchatel to the Lake of Morat along the river Broye, a distance of 6 km. (3.7 miles).

Between Thun and Scherlingen, which latter port, built in 1862, has been put out of commission in 1925, the boats run down a canal for 500 m. (0.31 mile), then follow the Aar for another 500 m. (0.31 mile) as far as Schanday where they reach the lake. At the other end of the

Table 225

DIMENSIONS OF SWISS LAKES.

LAKE.	Altitude.	Area.	Maximum Depth.	Maximum Width.	Maximum Length
	(Feet)	(Sq. miles)	(Feet)	(Miles)	(Miles)
Joux	3310	...	...	0.93	5.6
Neuchâtel	1417	84.9	505	6.2	24.85
Morat	1427	...	...	...	5.6
Bienne	1417	...	...	2.5	9.3
Thun	1837	18.5	715	2.2	11.2
Brienz	1857	11.6	850	1.7	8.7
Lucerne	1434	86.5	820	2.0	23.6
Lowerz	1480	...	...	0.32	2.8
Sempach	1663	...	...	0.155	5.0
Hallil	1368	...	...	...	...
Zug	1368	14.7	649	2.5	8.7
Aegeri	2378	2.7	...	0.93	3.4
Sils	5895	...	233	0.93	4.35
Silvaplana	5876	...	253	0.93	1.86
St.-Moritz	5987	...	..	0.435	1.24
Wallen	1388	9.0	495	1.24	9.3
Zurich	1342	33.9	469	2.36	24.5
Do. (Upper)	Do.	...	(164)	...	7.15
Constance	1299	183.4	482	8.7	38.5
Untersee	1299	(24.7)	(151)	...	...
Geneva	1230	224 7	1015	8.57	45.1(1) 55.8(2) 44.9(3)
Orta	951	...	...	1.24	7.5
Maggiore	646	83.4	1220	3.1	40.4
Varese	...	...	..	2.5	5.6
Lugano	899	19 5	945	1.86	25.5(4) 14.9(5)
Como	650	56.4	1345	2.5	29.8
Garda	213	142.8	1135	11.2	31.7
Iseo	610	23.5	823	3.1	77.7

(1) to (3) Distances measured along the shores and median distance.
(4) and (5) Median distance and as the crow flies.

Table 226.

SPEED OF SERVICES ON THE SWISS LAKES AND ON THE RAILWAYS RUNNING ALONG THE SHORES.

(Railway services are shown in italics).

RUN.	Distance.		Time of departure.	Time spent.	Speed.		Number of stops.	—
	Km.	Miles.			Km./h.	M. p. h.		
Lake of Neuchatel.								
Neuchâtel-La Sauge . . .	9.0	5.6	1 30 p. m.	0.37	14.6	9.1	...	Crossing.
La Sauge-Sugiez . . .	6.0	3 7	9.05 a. m.	0.35	10 3	6.4	...	On river.
Yverdon-Neuchâtel . . .	31.0	19.3	1.35 p. m.	2.40	11.6	7.2	7	
Do. *(L.B.)*	*36.0*	*22.4*	6.05 a. m.	0.31	70.0	43.5	...	*S.F.R.*, via Colombier.
Lake of Bienne.								
Bienne-Neuveville	18	11.2	6.45 p. m.	1.05	16.6	10.3	2	
Do. *(L.B.)*	*14*	*8.7*	R *9.59* a. m.	*0.14*	*60.0*	*37.3*	*3*	*S.F.R.*, via Twann.
Lake of Thun.								
Thun Bhf.-Interlaken Th. .	30 4	18.9	12.27 p. m.	1.53	16 1	10.0	8	
Do.	21.7	13.5	Special	1.10	18.6	11.6	...	
Do. (L.B.)	*27*	*16.8*	*9.13* a. m.	*0.43*	*37.6*	*23.4*	*1*	*B.L.S.*, via Spiez.
Do. (R.B.)	*23*	*14.3*	*10.37* a. m.	*1.23*	*16.6*	*10.3*	*9*	Metre gauge.
Lake of Brienz.								
Interlaken Br.-Brienz . . .	20.8	12.9	5.23 p. m.	1.19	15.8	9.8	3	
Do.	15.0	9.3	Special	0.48	18 7	11 6	...	
Do. (R.B.)	*17*	*10.6*	*3.30* p. m.	*0.24*	*42.5*	*26.4*	...	*S.F.R.*, Brunigbahn.
Lake of Lucerne.								
Beckenried-Gersau . . .	5	3.1	9.40 a. m.	0.13	23.1	14.3	...	Crossing.
Lucerne Stat.-Vitznau . .	14.0	8.7	9.38 a. m.	0.43	19.5	12.1	...	
Do. -Stansstad .	9.5	5.9	10.46 a. m.	0.29	20.2	12.6	...	
Do. -Fluelen . .	33.5	20.8	9.20 a. m.	2.14	15.0	9.3	8	
Do. (R.B.)	*51*	*31.6*	*9.44* a. m.	*1.05*	*47.1*	*29.3*	*2*	*S.F.R.* via Brunnen.
Lucerne Alpnachstad . .	5	3.1	10.46 a. m.	0.49	18.5	11.5	1	
Do. (L.B.)	*13*	*8.1*	*9.08* a. m.	*0.21*	*37.1*	*23.1*	...	*S.F.R.* Brunigbahn.
Lake of Zug.								
Zug-Arth-Goldau	12	7.4	R 4 54 p. m.	0.55	13.1	8.1	2	
Do. (R.B.)	*16*	*9.9*	8 21 a. m.	0 16	60.0	37.3	...	*S.F.R.* via Walchwil.
Lake of Zurich.								
Zurich-Meilen	14	8.7	10.00 a. m.	0.38	22.1	13.7	...	
Do. (R.B.)	20	12.4	R *1.34* p. m.	*0.26*	*46.2*	*28.7*	*3*	*S.F.R.* Crossing.
Zurich-Rapperswil . . .	28	17.4	8.10 a. m.	1.50	15.3	9.5	8	
Do.	26	16.2	Through	1.30	17.4	10.8	...	
Do. (R.B.)	*36*	*22.4*	R *9.09* a. m.	*0.49*	*44.1*	*27.4*	*6*	*S.F.R.*, via Meilen.
Do. (R.B.)	*43*	*26.7*	R *8.08* a. m.	*0.50*	*51.6*	*32.0*	*4*	*S.F.R.*, via Uster.
Do. (L.B.)	*41*	*25.5*	*9.24* a. m.	*0.46*	*46.1*	*28 6*	*3*	*S.F.R.* via Pfäffikon.

TABLE 226. (*Continued*).

RUN.	Distance.		Time of departure.	Time spent.	Speed.		Number of stops.	—
	Km.	Miles.			Km /h.	M. p. h.		
SILVAPLANASEE.								
Sils Maria-Campfer . . .	6	3 7	9 30 a. m.	0.25	14.4	8 9	1	
LAKE OF CONSTANCE.								
Romanshorn-Friedrichsh. .	12	7 4	7.28 a. m.	0.40	18.0	11.2	...	Crossing.
Rorschach- Do. .	19	11.8	6.20 a. m.	0.55	20 7	12.9	...	Do.
Romanshorn-Lindau . . .	23	14 3	7 35 a. m.	1.10	19.7	12.2	...	Do.
Rorschach- Do.	21	13 0	11.23 a. m	0.50	25.2	15.6	...	Do.
Bregenz-Constance (R.B.)	60	37.3	11.50 a. m.	3 40	16.4	10 2	11	
Do. (L.B.)	*60*	*37.3*	*2.50* p. m.	*1.51*	*32.7*	*20 3*	*6*	*Austr. F.R.* and *S.F.R.*
UNTERSEE.								
Constance-Schaffhausen . .	46	28.6	10.10 a. m.	2.35	17.8	11.1	5	
Do. (L.B.)	*47*	*29.2*	*2.28* p. m.	*1.19*	*35.7*	*22.2*	*15*	*S.F.R.*
Stein a/R.-Schaffhausen . .	20	12.4	11.20 a. m.	0.55	21.9	13.6	...	
Do. (L.B.)	...	...	4.49 p. m.	0 36	...	...	6	*S.F.R.*
LAKE OF GENEVA.								
Nyon-Thonon	17.8	11.1	10.20 a. m.	0.45	23.7	14.7	...	Crossing.
Evian-Ouchy	11.9	7.4	11.40 a. m.	0.28	25.5	15.8	...	Do.
Meillerie-St. Gingolph . .	7.0	4.35	3.53 p. m.	0.19	22.1	13.7	...	Do.
Geneva-Nyon	21 3	13.2	9.25 a. m.	0.48	26.6	16.5	...	
Geneva-St. Moritz (L.B.)	99+23	61.5+14.3	10.55 a. m.	4.50 +33	14.2	8.8	21	*S.F.R.*, via Evian.
Do. (R.B.)	97+23	60.3+14.3	1 50 p. m.	4 25 +33	30.0	18.6	11	*S.F.R.* via Ouchy.
Do. (L.B.)	*89*	*55.3*	R *5.23* p. m.	*3 10*	*25.9*	*16.1*	*18*	*P.L.M.* and *S.F.R.* via Evian.
Do. (R.B.)	*112*	*69.6*	*4.42* p. m.	*2.00*	*66.0*	*41.0*	*6*	*S.F.R.*, via Lausanne.
Italo Swiss Lakes.								
LAKE MAGGIORE.								
Intra-Laveno	5	3 1	6.40 a. m.	0.15	20.0	12.4	...	Crossing.
Cannero-Luino	4	2.5	8.00 a. m.	0 20	12 0	7.4	...	Do.
Luino-Pallanza	18.7	11.6	10.30 a. m.	0.50	22.4	13.9	...	
Arona-Pallanza	27	16.8	...	1.10	23.1	14.3	1	
Do. (R.B.)	*26*	*16.2*	*10.18* a. m	*0.32*	*48.7*	*30.3*	*2*	*Ital. St.* via Stresa.
Arona-Luino	50	31.0	2.15 p. m.	2.40	19.8	12 3	7	
Do. (L.B.)	*45*	*28.0*	...	*1.05*	*41.5*	*25.8*	*5*	*Ital. State*, via Sesto Calende.
LAKE OF LUGANO.								
Lugano-Capolago	15	9 3	R 7.15 p. m.	0.21	22.5	14.0	1	
Do. (R.B. + L.B.)	*14*	*8.7*	2.40 p. m.	0 17	49.4	30.7	...	*S.F.R.*, via Melide.
Lugano-Ponte Tresa . . .	23	14.3	8.20 a. m.	1.25	17.0	10.6	6	
Do. (R.B.)	*12*	*7.4*	*7.50* a. m.	*0.27*	*26.7*	*16.6*	*6*	Ferr. Luganesi, metre gauge.

journey they run through 2 650 m. (1.65 miles) of the canal opened in 1892 between Daerligen and Interlaken.

In the same way, before reaching the Lake of Brienz, they follow the river Aar for 1 300 m. (0.81 mile).

The boats from the Untersee work down the Rhine for 20 km. (12.4 miles) between Stein am Rhein, at the western end of the lake, and Schaffhausen.

Regular boat services along each shore and cross services are maintained on the major lakes. Besides this, there is usually a railway line along one or both shores. Table 226 compares the distances and average speeds of these different services.

(To be continued.)

621.133.1

Mechanisation of the control of the fuel used and the distance run by locomotives.

The « Rona » locomotive meter,

by N. M. MOTCHAROFF,

Mechanical Engineer, Locomotive Department, Rumanian State Railways, Bucharest,

and A. S. SOKOLOFF,

Mechanical Engineer, Messrs. Louis Sacré & Frères, Liége (Belgium).

(*Revue Universelle des Mines.*)

We have already seen (*Revue Universelle des Mines*, 1933, Nos. 20 and 21) (1) that the « Rona » meter enables us to check the coal allowances whilst the locomotives are running, and obliges the drivers, under penalty of being fined automatically, to use preferably high steam pressure in the steam chests.

The Rona meter will meet the conditions imposed on it even more fully, when it is possible with it to verify the fuel allowances when running with the regulator shut, and whilst standing under pressure.

Then too it is essential that the drivers are given a visual indication showing how, by a proper use of the reversing lever, to get the greatest tractive effort possible or, in the case of a lighter train, to make the greatest possible fuel economy.

To meet these requirements, the Rona meter has been fitted with two devices, one forming an integral part of the meter itself, and the other attached to the usual speed recorder. These two devices will be briefly described hereafter.

(1) See also *Bulletin of the Railway Congress*, March 1934, p. 293.

Device for indicating the fuel consumption when running with the regulator shut and when standing.

The Rona meter is completed by a fourth totaliser independent of the three others previously described, and directly driven by the locomotive. This totaliser (17, figs. 1 and 2), fitted in the driver's cab, is driven by a chain driven in turn by clockwork so designed that the number of turns it makes per hour corresponds to the fuel allowances expressed in money units when running with the regulator shut and when standing under pressure.

So that the totaliser only functions under these conditions, its drive is made dependent on two servo-motors (3 and 5). As long as the boiler is not fired at a sufficiently high rate, and so long as the pressure remains under 4 kgr/cm² (57 lb. per sq. inch), the steam entering the cylinder (5) above the piston (8) is not able to overcome the spring (6). The piston (8) remains stationary and with it the small rod (12) carrying the shoe (14). In this position this shoe presses the chain driving the totaliser (17) against a second shoe (15), and in so braking it stops the totaliser.

The totaliser is also stopped in the

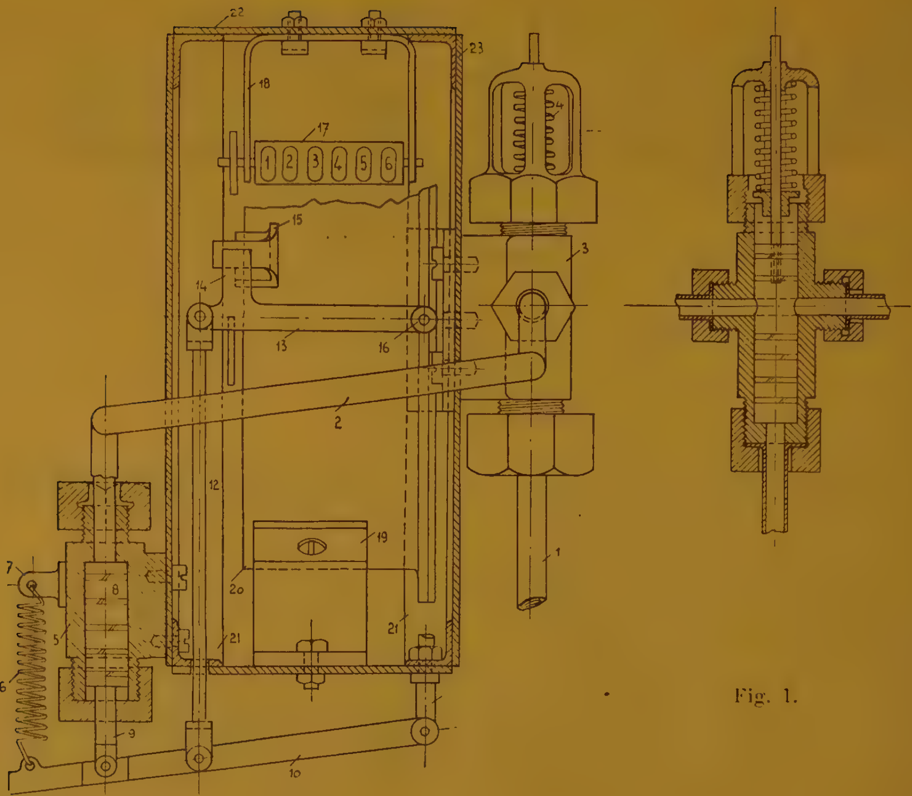


Fig. 1.

same way when the boiler is cold and when running with the regulator open. In this latter event, the steam from the pipe (1) passes into the upper cylinder (3) and forces upwards the hollow piston of this cylinder, thereby closing it to the tube (2) taking steam from the boiler to the lower cylinder (5). Consequently, the piston (8) remains stationary and the totaliser (7), as we have just explained above, is stopped.

As soon as the regulator is closed, however, the piston of the upper cylinder returns to its normal position and puts the boiler into communication with the tube (2). If at this moment the boiler pressure exceeds 4 kgr/cm² (57 lb. per sq. inch), the spring (6) gives way and the piston (8) comes down with the rod (12). The chain driving the totaliser (17) is no longer braked and the totaliser again works normally.

Indicator of cut-offs in terms to the speeds.

When the tractive effort diagrams with fully open regulator are examined, some of the speeds worked are always found to correspond to the given cut-offs. Let the curve AB (fig. 3) represent, for any locomotive, the greatest tractive effort for a steam consumption of X kgr. per hour.

We see a speed of 45 km. (28 miles) an hour should be attained with 50 %

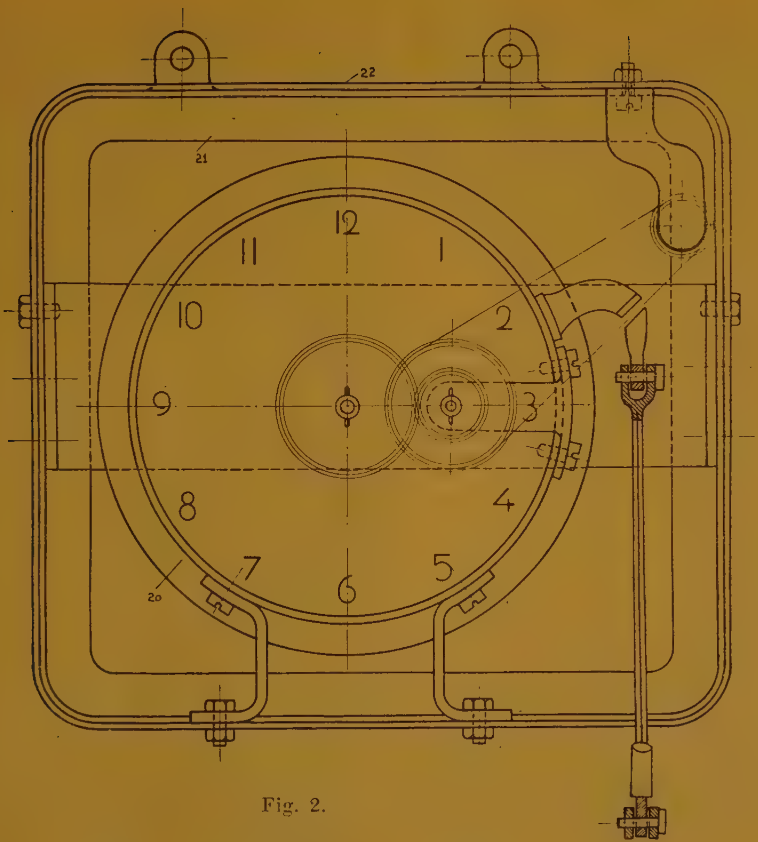


Fig. 2.

cut-off; 63 km .(39.1 miles) with 40 %; 95 km. (59 miles) with 30 %. From the curve AB we can ascertain the speeds corresponding to the intermediate cut-offs.

It should be noted that if the weight of train is reduced and if the running times remain as laid down, there is no need at all to force the locomotive to the rate of curve AB : for example a speed of 45 km. (28 miles) an hour can be obtained with 38 % cut-off if the trailing load corresponds to the tractive effort of curve CD, or with 26 % cut-off if the train is lighter and if the cut-off corresponds to the tractive effort of curve EF. The same argument can be applied to all speeds attained with smaller cut-offs.

If, however, light trains worked to the speeds of heavy trains are concerned, the setting to curves CD and EF is only recommended when corresponding to a high enough total engine output. Otherwise, i.e. if it is curve AB that corresponds to the maximum output, the cut-off should be regulated by this same curve and the regulator shut as soon as the speed exceeds the fixed limit.

If, therefore, the speed indicator has an additional finger controlled by the reversing lever through suitable operat-

ing gear provided for the purpose, *the greatest tractive effort will be obtained for such a position of the reversing lever as will make the additional finger concide with the normal finger of the speed indicator.* This setting should be kept to so long as the maximum speed is not reached.

In the device as manufactured, the

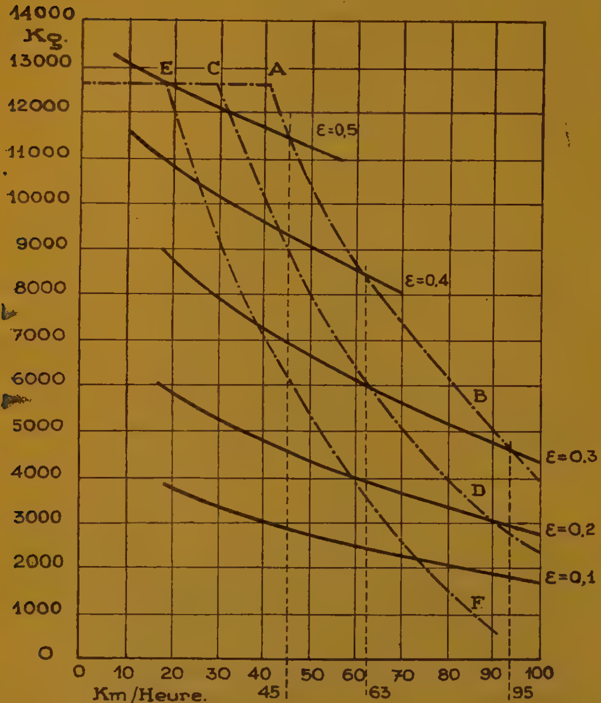


Fig. 3.

Note: Kg. = Kilogrammes of steam used per hour. — Km/heure = Kilometres per hour.

additional finger is red, and the ordinary one black. For simplicity the first will be called « *the red finger* », and the latter « *the black finger* ».

Contrariwise, *the greatest fuel economy will be obtained with the smallest possible cut-offs,* i. e. *for that position of the reversing lever in which the red finger is the farthest past the black towards the high-speed region.* This setting, of course, is conditioned by the train working, as the actual speeds must not be lower than the booked timings.

In order to apply the above principle we proceeded as follows : on the cover of the speed recorder a small bracket *i* (fig. 4) is fastened with a fixed spindle *k* on which is fitted a lever *b* with a shaft *m* free to oscillate inside the lower bearing thereof. On the end of this shaft *m*, a toothed cam *c* is fitted, this cam being driven by a small pinion *d* keyed on the spindle *a*. This latter spindle is driven by flexible steel wire inside the rigid tube *t*; the other end of this wire is secured to the bearing of the pinion (23) (figs. 5 and 6) controlled by the reversing lever B.

On the other end of the spindle *m* (fig. 4) a pinion *e* is fixed, transmitting by a chain the angular movements of the cam *c* to a second pinion *f* loose mounted on the fixed spindle *k*. A red finger *g*, fastened to the pinion *f* reproduces in terms of the speed all the angular movements of the cam *c* the contour of which is such that the angular displacements of the spindle caused by the setting of the reversing shaft, and the movements of the red finger *g*, comply with the principles given above.

In this way, *the locomotive will develop the greatest tractive effort,* when the driver, by frequently altering the position of the reversing lever, *keeps the black finger covered by the red, and the greatest fuel saving for a given speed* will be effected, depending upon the running conditions of the train, *when the red finger goes the farthest possible beyond the black,* i.e., the farther the red finger descends down the scale, the smaller will the cut-offs be, and the less the steam and consequently the fuel used.

Analytical examination of the properties of the « Rona » meter.

Let us consider the application of a Rona meter to a locomotive for which all the characteristic data have been established by scientific tests. As example, let us take a 0-10-0, class E, locomotive of the Russian State Railways, the features of which Professor Lomonossoff published in his book « Die Locomotivversuche in Russland » (Berlin, 1926).

The conclusion is reached in this book that, for this type of engine, there is a rational method of regulating it, with the regulator partly open, which at first view seems to contradict our affirmation that the most scientific setting is always with full open regulator.

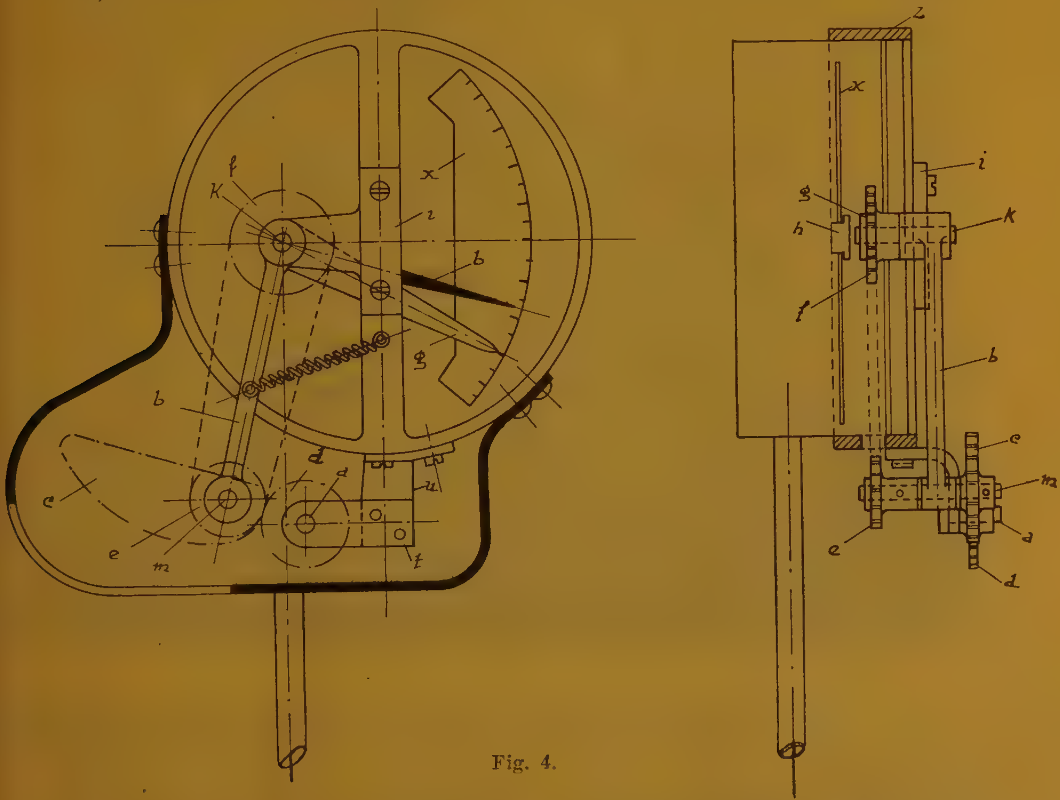


Fig. 4.

Let us examine a few characteristic diagrams taken from the above mentioned work, using the following notations :

C = coal consumption, in kgr.
F_K = tractive effort at the driving wheel tread.
H = heating surface, square metres.
K = Calorific value of the coal used (7 200 calories = 12 950 B.T.U./lb.).
N_K = power measured at the driving wheel tread.
U = Steam used per hour in kgr.
V = Speed, in kilometres per hour.

Figs

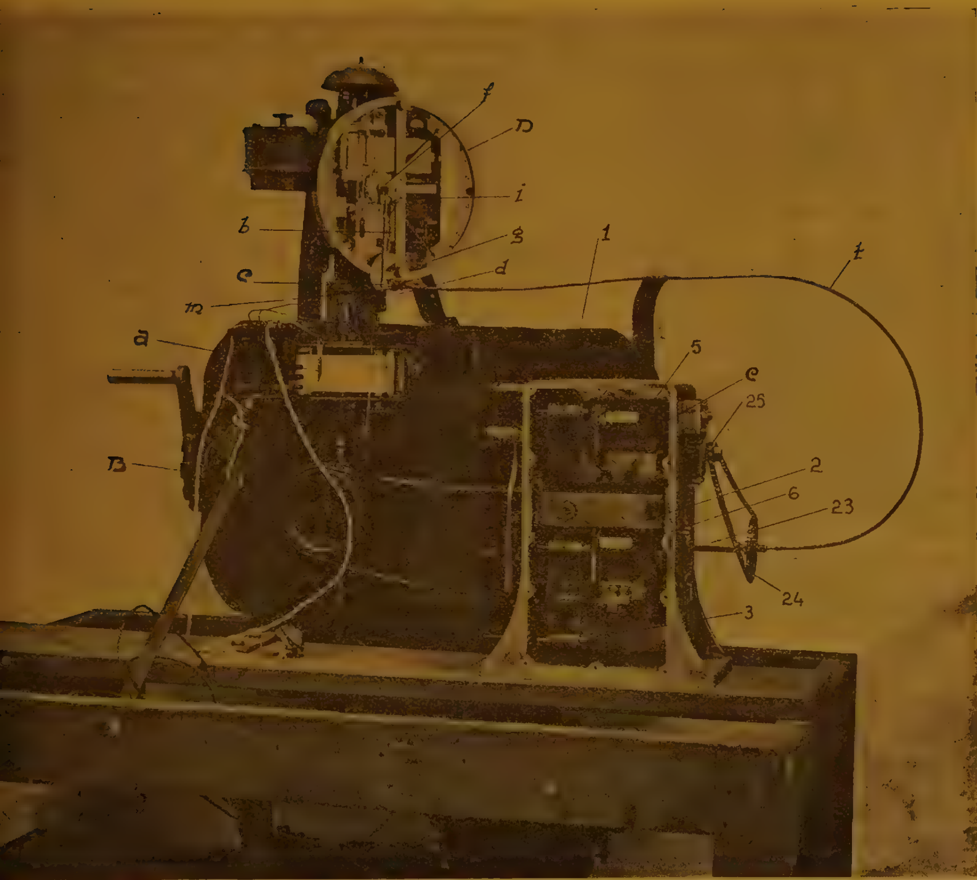
The Rona meter under test. — a = Paper roll which unrolls proportionately to the dista
recorded thereon. — C = The Rona meter. — D. = The speed recorder. — B = T

Y = Efficiency of the locomotive, %.
Z = Steam used per hour per m^2 of heating surface per hour.
ε = Cut-off.
ρ = Regulator opening.

Figure 7 shows the tractive effort at the driving wheel tread F_K, in terms of the speed V and the cut-off ε. The continuous lines refer to the full open regulator position (ρ = 1/1) and the bar lines to the partly open regulator (ρ = 1/85 and ρ = 1/22.5).

Figure 7 also gives the power curves corresponding to an hourly steam consumption of Z = 30 and Z = 50 kgr./m^2 of heating surface with full open regulator (ρ = 1/1).

Figures 8, 9 and 10 are diagrams of



6.

elled. The cut-offs used on different section sof the run on which the trials were made were
ersing lever. t = Tube containing the flexible steel wire driving the cut-off indicator.

the steam consumption per horse-power at the driving wheel tread $\left(\frac{U}{N_K}\right)$ corresponding to the driving forces as determined by the diagrams, figure 7.

The diagrams, figure 11, give the coal consumption per kilometre $\left(\frac{C}{V}\right)$ in terms of the speed (V) and the cut-off (ϵ), the regulator being full open (continuous line $\rho = 1/1$), and partly open (bar lines, $\rho = 1/85$).

Figure 12 gives the diagram of the coal consumption (C) in terms of the hourly production of saturated steam (U).

The diagrams of the overall efficiency of the locomotive in terms of the speed,

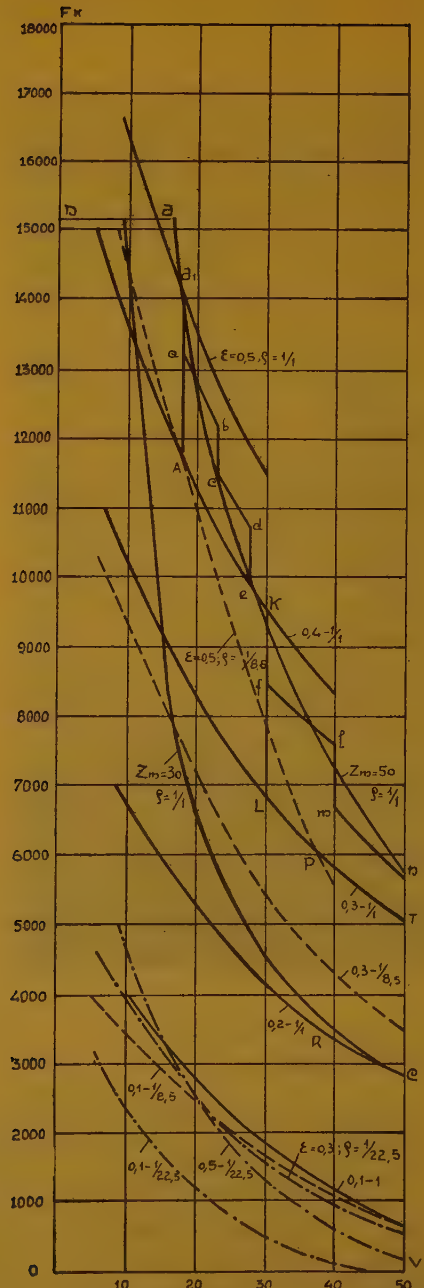


Fig. 7. — Tractive effort F_K at the driving wheel treads in terms of : A) the speed V; B) the steam consumption.

regulator opening, and cut-off, and the hourly consumption of saturated steam per m² of heating surface are given in figures 13 to 16.

The diagrams figure 7 (excepting that in broken lines *Da, abc, mn* and *a*, A K L T), 8 to 10 and 12 to 14, have been taken from Professor Lomonossoff's book; all the others we have developed ourselves. The values $\frac{C}{V}$, figure 11, have been calculated by the usual formula

$$\frac{C}{V} = \frac{U}{N_K} \times \frac{C}{V} \times \frac{F_K}{270}$$

by replacing therein U, C and F_K by their respective values found from figures 7, 10 and 12. The values of the efficiency have been calculated from the formula

$$Y\,\% = \frac{F_K \times 1000}{C/V \times K \times 427}$$

by replacing therein F_K by the values obtained from figure 7.

The analysis of these diagrams shows that the different combinations in which an engine should be worked should be limited preferably to :

a) Hourly steam consumptions not falling below Z = 25 to 30 kgr./m² (5.1 to 6.1 lb. per sq. foot) of heating surface. If the consumptions become equal to or less than 20 kgr. (4.1 lb. per sq. foot), the efficiency becomes too low.

b) Cut-offs of 20 % or over. Earlier cut-offs give too low efficiency, and

c) Regulator openings of ρ = 1.85 or more because with smaller openings, the efficiency of the locomotive is reduced.

The examination of these diagrams also shows that the best settings correspond to the conditions of table I.

To obviate incorrect settings, see *a*, *b*, and *c* above, Professor Lomonossoff's proposal to close the regulator each time the load on the draw-bar drops or the

speeds falls below the limit of the working timetable, seems to us sound. The use of cut-offs which are satisfactory as regards fuel consumption ought not, be it noted, to prevent the locomotive from hauling heavy trains with very sharp timings. From an economic point of view, this is more important than long runs with a locomotive developing greater efficiency.

The above argument means that the Rona meter should be adapted to each

TABLE I.

Regulator opening. ρ	Cut-off, ε %	Speed V, km./hour.
1/1	50	10-30
1/1	40	15-40
1/1	30	20-45
1/1	20	25-50
1/8.5	50	10-35
1/8.5	30	10-35

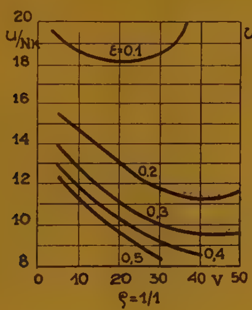


Fig. 8. — ρ = 1/1.

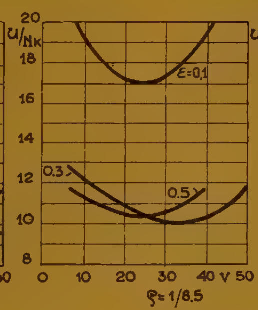


Fig. 9. — ρ = 1/8.5.

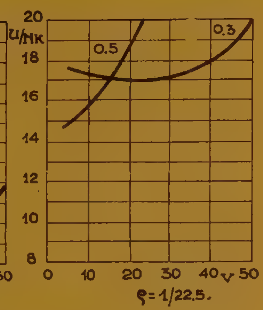


Fig. 10. — ρ = 1/22.5.

Saturated steam used per horse-power at the driving wheel treads U/N_K, in kgr, in terms of : A) the speed V ; B) the regulator opening ρ ; and C) the cut-off ε.

particular type of locomotive in such a way that the drivers, when endeavouring to increase their coal premium, do not exceed the running time allowed and do not try to avoid, on one pretext or another, having to work heavy trains.

We may add that the Rona meter must meet the following conditions : the coal premium for each 100 gross tonne-kilometres, when hauling heavy trains, ought to be higher than that for light trains. Then too, when working trains of the same weight over the same section, the premium as worked out by be Rona meter should be greater for the faster train even if a greater quantity of fuel were used.

We consider that such a setting of the Rona meter not only *solves the question of how to calculate the coal premium, but at the same time automatically* and more satisfactorily *determines the premium for time made up in running and for the weight hauled.*

In the following we will make a distinction between *two settings of the locomotive, the first suggested by us* in accordance with the above principles which we will call « *controlled setting* », and the other, preferred by the drivers, characterised by rarely altering the regulator position, we will describe as « *usual setting* ». The characteristics of these settings, which we quote as an example, are given in table II.

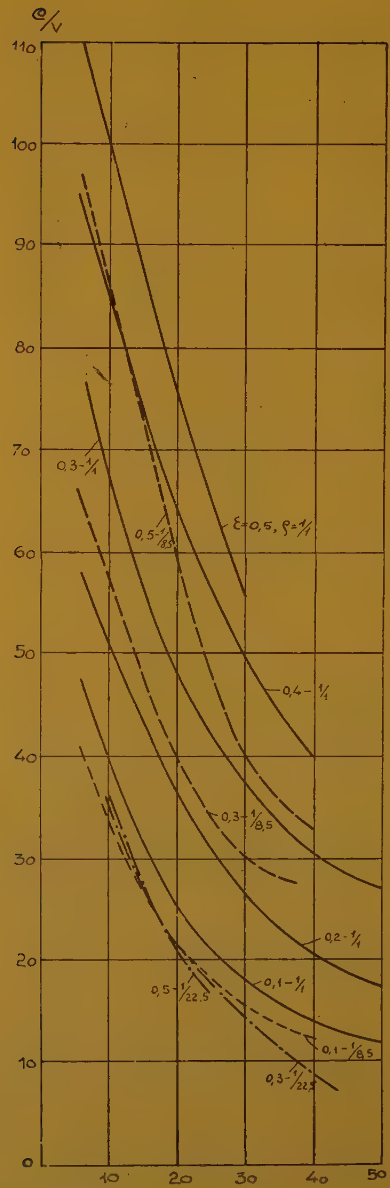


Fig. 11. — Coal consumption per kilometre run, C/V in kgr.. in terms of: A) the speed V; B) the regulator opening ρ; C) the cut-off ε.

Table II.

Controlled setting.		Usual setting.	
Full open regulator : ρ = 1/1.			
Fig. 17.		Fig. 18.	
Cut-offs, %	Speeds, km./h.	Cut-offs, %	Speeds, km./h.
50	13 -17.5	50	13 -17.5
47	17.5-22.5		
45	22.5-27.5		
40	27.5-30	40	17.5-30
37	30 -40		
30	40 -50	30	30 -40
For low draw-bar pulls.			
30	30 -40	By increasing the speed above the given limit, — all regulator openings and in extreme cases — the latter is shut.	
20	40 -50		
Regulator shut for speeds above those dealt with above.			

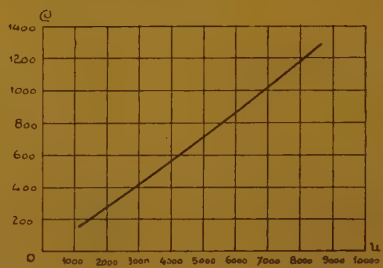


Fig. 12. — Coal used per hour, in terms of the saturated steam produced per hour U.

Let us examine diagrams 17 and 18, and see how the Rona meter can help in the calculation of the premiums for time made up and for the tonnage hauled. [Diagrams 17 and 18 have been completed by the diagrams of figure 11 for the coal used in terms of the speed (V) and the cut-off (ε).]

Let us now transfer the coal allowances of figure 20 to diagrams 17 and

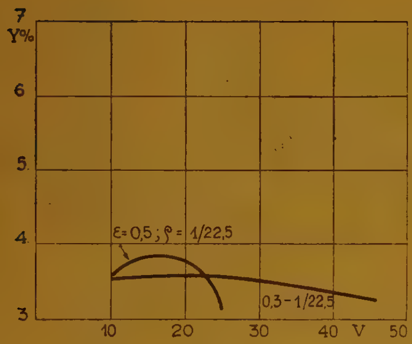


Fig. 13.

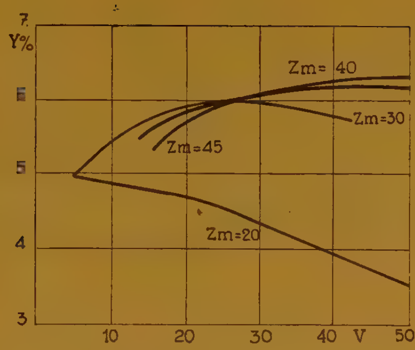


Fig. 14. — Overall efficiency of the locomotive Y % in terms of : A) the speed V; and B) the consumption of saturated steam Z_m in kgr./m² of heating surface per hour.

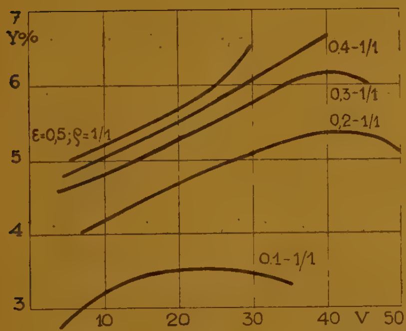
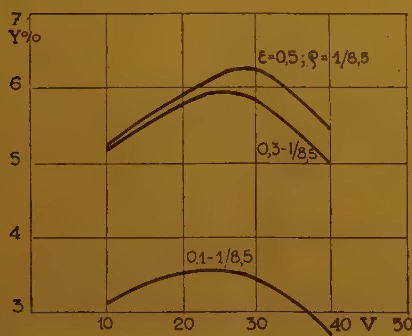


Fig. 15.



Figs. 13, 15, 16. — Overall efficiency of the locomotive Y % in terms of : A) the speed V; B) the regulator opening ρ ; C) the cut-off ϵ.

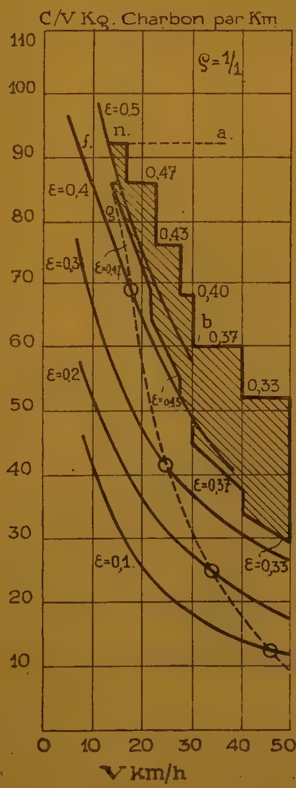


Fig. 17.
Controlled setting.

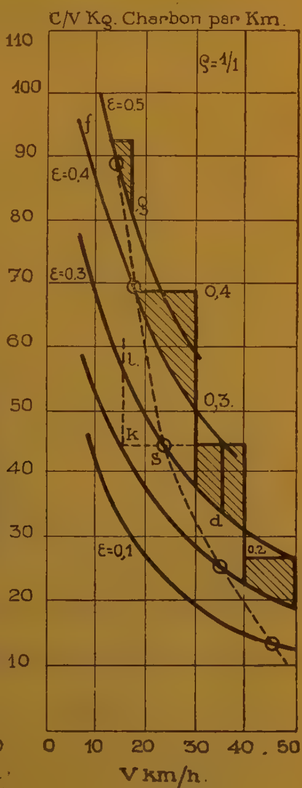


Fig. 18.
Usual setting.

Note · C/V kg. charbon par km. = C/V kgr. coal per km.

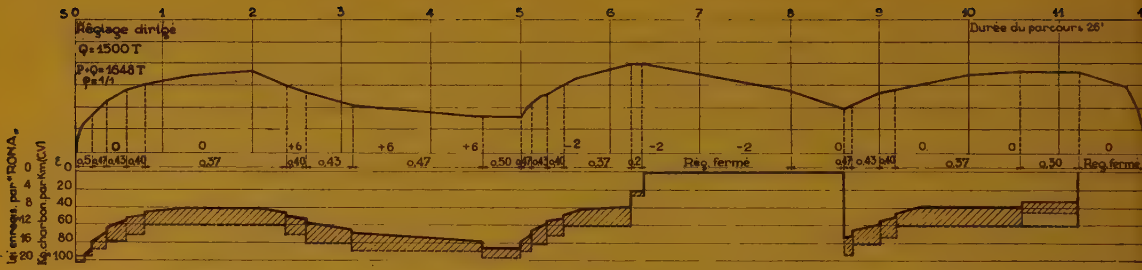


Fig. 19.

Explanation of French terms :

Réglage dirigé = Controlled setting. — Durée du parcours = Time of run. — Lei enregist. par Rona = Lei recorded by the Rona. — Reg. fermé = Regulator shut.

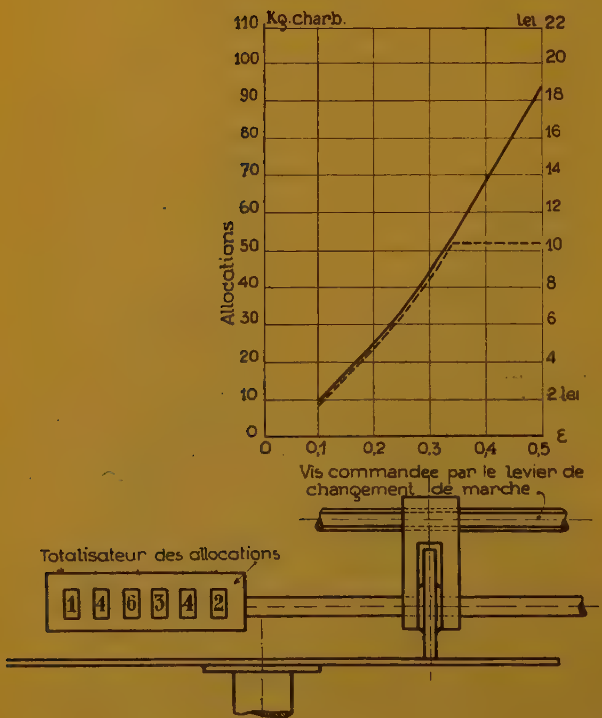


Fig. 20.

Note. — Vis commandée... marche = Screw driven by the reversing lever. — Totalisateur des allocations = Totaliser of the fuel allowances.— Allocations = Allowances.

18 (see points surrounded by circles transposed on to the consumption curves). Let us draw through the points so obtained a dotted line which divides the fuel consumption curves into two parts : the ordinates of the curve to the left of their point of intersection with the fuel allowance dotted line have greater values than the corresponding allowances, whereas the ordinates to the right of the dotted line are smaller than the allowances.

Thus for example, when running at = 30 % cut-off at speeds of between 16 and 40 km. and hour, the fuel allowance per kilometre registered by the Rona meter will always correspond with the straight line KS*m* (44 kgr. of coal), see fig. 18.

At 16 km. an hour, the consumption in excess of the allowance will be given by the straight line K1 (11 kgr. of coal) and the driver will lose 11 : 5 = 2.5 lei per kilometre run in such a setting.

At 40 km. an hour, the allowance will exceed the expenditure of the line *md*, so that the value of this line, 14 kgr. of coal or 14 : 5 = 2.8 lei will be the driver's premium recorded by the Rona meter.

This example shows that the Rona meter punishes the driver who uses cut-offs of ϵ = 30 % at speeds below 22-

23 km. an hour. Such a setting of the Rona meter is also justified by the further consideration that the coefficient of use of the locomotive, as is shown by figures 13-16, when the cut-off $\epsilon = 30\ \%$ and the speed V is below 23 km. an hour is not very good and the tractive effort (see fig. 7) is not high enough. Poor use is made of the locomotive as a result, especially when running heavy trains.

The same argument enables us to decide the fuel allowances for 50, 40 and 20 % cut-offs (see figs. 20, 17 and 18).

From figure 17, the forcing of the engine, as for example with 50 % cut-off at 30 km. an hour, is only possible when the boiler is fired very skilfully, which is recompensed by a large premium corresponding to the part of the straight line *ab* = 35 kgr. of coal or 35 × 0.2 = 7 lei for each kilometre run. This premium is entirely justified by the advantages to the railway through the higher speed of heavy trains.

If we take the 0-10-0, class E, locomotive, the benefit due to this setting is seen in a high locomotive efficiency (see figures 13 to 16). If figures 17 and 18 be compared, we also see how much better the locomotive is employed when the setting of the reversing gear is « *controlled* », and how much greater chance the driver has to add to his premium (see cross hatched area) in the first case than in the second.

Locomotives of greater power at early cut-offs must, of course, be set in quite another way than that shown on figs. 17 and 18.

TABLE III.

Fig. No.	Weight of the train. Metric tons.	Way engine was run (setting).	Time run Min.	Difference between the times the run takes (base = time of run with the usual setting) Min.	Fuel consumption in kgr.	Fuel consumption in units of the premium (5 kgr. =1 lei) Lei.	Difference of base consumption with usual setting Kgr.	Difference of base consumption with usual setting per 100 gross t./km. %.	Allowance recorded by the Rona Lei.	Premium (col. 10 less col. 7) Lei.	Difference in premium (base : premium with usual setting). Lei.	Difference in premium (base : premium with usual setting). %.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
—	1500	usual $\rho = 1/1$	26	—	525	105	—	—	128.6	23.6	—	—	Full open regulator.
—	1500	controlled $\rho = 1/1$	23.2	—2.8	537	107.4	+12	+2.06	138.2	30.8	+7.2	+30.6	»
19	1500	controlled $\rho = 1/1$	26	0	483	96.6	—42	—7.9	128.4	31.8	+8.2	+34.4	»
—	750	usual $\rho = 1/1$	20.5	—	325	65	—	—	80	15	—	—	»
—	750	controlled $\rho = 1/1$	20.5	—	293	58.6	—32	—9.7	75	16.4	+1.4	+ 9.3	»
—	750	controlled $\rho = 1/1$	19.8	—0.7	316	63.2	—9	—3.05	80.8	17.6	+2.6	+17.5	»
—	750	$\rho=1/8.5$ $\epsilon=0.5$ $\epsilon=0.3$	19.8	—0.7	332	66.4	+1.4	+2.22	—	—	—	—	Setting recommended by Professor Lomonossoff.

The best « *controlled setting* » and the most exact can be obtained for each given type of locomotive by a detailed examination of the characteristic data of the locomotive as obtained by carefully controlled scientific tests. To verify the above principles, we have drawn, by Lipetz's grapho-analytical method, the speed-distance curves for two trains, one of 1 500 tons and the other of 750 tons both hauled by a 0-10-0, class E, locomotive. These curves have been drawn one for a *controlled setting* and the other for the *usual setting*. The section of line considered was 12 km. long, with a varying gradient section and maximum gradients of 1 in 166.

Below each speed curve we have drawn a broken line representing the fuel consumption per kilometre and a bar line for the corresponding fuel allowances. The cross-hatched area between these two lines represents the drivers' premiums.

Seven diagrams have been prepared, of which that for a 1 500-ton train on the *controlled setting* principle is the only one reproduced here. Table III gives the results of this graphical examination. We see therein that :

1. Working the 1 500-ton train on the « *controlled setting* » principle, the time of the run can be reduced by 2.8 minutes (11 %) or the time can be retained and a fuel saving of 7.9 % effected. The driver's premium will be increased 30.6 %, whilst the fuel consumption increases 2.06 %. In the second case, the driver's premium will be 34.4 % higher.

2. When hauling the 750-ton train on the *controlled setting* principle, a 9.7 % fuel saving can be made over that with the usual setting, the same time being taken as in the first case.

3. If the train is hauled with the engine worked as suggested by Professor Lomonossoff (regulator opening = 1/8.5, and cut-off = 50 to 30 %) 0.7 minute may be saved on the run but that means an increased fuel consumption of 2.22 % relatively to that with the usual setting.

4. When the same train is worked using the *controlled setting,* not only is the time of the run reduced by 0.7 minute but a fuel saving of 3.05 % relatively to the usual setting is also effected.

The driver's premium during these same running times and with *controlled setting* is increased by 9.3 %, and if the running time is reduced by 0.7 minute the premium of the driver is increased by 17.5 %. If the regulator opening be 1/8.5 the premium will not be recorded because the Rona meter will not work under such conditions. If, however, the management should decide to use such regulator openings with low pressures, the meter can be set accordingly, corresponding to the dotted diagram of figure 20. In the case of heavy trains it should be noted that the premium is greater than with light trains : 7.2 or 8.2 lei for the 1 500-ton trains and 1.4 or 2.6 for the 750-ton trains.

[621. 132.8 (42)]

New turbine-driven 4-6-2 express locomotive, London Midland and Scottish Railway.

(From *The Railway Gazette*).

It has become the fashion when referring to any development of an outstanding character in locomotive practice to label it a « bold experiment ». We do not, however, propose to follow this example in dealing with Mr. Stanier's new turbine express engine recently completed at the Crewe works of the London Midland and Scottish Railway; not because of inability to realise that the adoption of this principle of utilising steam for locomotive purposes still remains largely an experiment, and that courage is required in taking such a step at the present juncture. Rather is it for the reason that, having had ample facilities for studying the design and seeing the engine grow up in the Crewe works from the time the frame plates were laid down to that at which the complete locomotive stood ready for painting and testing, we have been able to convince ourselves that in this design every effort has been made to simplify the general layout and follow as closely as circumstances permit what may be termed orthodox locomotive lines. The main and, indeed, the only real difference from a structural point of view is the substitution of turbines and geared transmission mechanism for the more usual reciprocating machinery consisting of cylinders, steam distributing valves, and other motion details. The locomotive closely resembles and is, indeed, identical in several major respects with the 4-6-2 express engines built at Crewe in 1933, *The Princess Royal* and *Princess Elisabeth*, of which class ten more are being constructed to substantially the same design at the present time.

The first question one is inclined to ask oneself in a matter of this sort is why a departure of the kind here involved should be undertaken at all. Turbine locomotives have already been tried out in this country and abroad, more particularly in Sweden, and a great deal of patience and ingenuity expended in the effort to make them show up advantageously in comparison with the reciprocating form of locomotive. Have the results been such as to warrant further trials and experimentation or not? Such a question is natural enough, but the main point for the chief mechanical engineer and other officers of a railway company to decide is whether the theoretical advantages of the turbine can be turned to profitable account on their particular line for dealing with the trains they have to haul under the conditions which actually apply. Once they have satisfied themselves that this can be done the next step is that of plotting a design which, in the judgment of those principally concerned, is the best to meet the circumstances of the individual case. This new locomotive of the L. M. S. R. is designed for an output of 2 000—2 500 H.P.; some of its axles carry a load of 24 tons, an unusually high figure in British practice, and made permissible, of course, by the improved torque of the turbine machinery and consequent elimination of hammer blow. The intention is to use it for hauling through express passenger trains of 500 tons loading or more between London and Glasgow at high average speeds and thus it will be brought into direct comparison with the piston type engines of the same general class. Fuel economy, increased power output and improved balancing, with consequent saving of the track and structures, themselves combine to provide a

goal worth aiming at, but there are further advantages which include uniformity of torque when running normally, together with an approximately double torque at starting and the facility to obtain an overload through the medium of the steam nozzles provided for the purpose. The fuel economy expected is 15 %, and this, we may assume, is calculated on a basis of comparison with a compound and not a single-expansion engine; otherwise it might seem to be too low a figure to justify such a definite departure from ordinary practice.

There will, as a matter of course, be criticism of the design of the locomotive apart from the principle on which it operates, and among such criticisms we expect to find one based on the fact that it is of the non-condensing type. It is, we know, urged by some that the absence of condensing apparatus robs the system of half its value. In support of this seemingly exaggerated claim they assert that the incorporation of a condensing system considerably reduces both the coal and water consumption, even to the extent of from 40 to 50 %, whilst, further, as the boiler system is a closed one, the quality of the feed water becomes more or less immaterial so far as the life of the boiler and the cost of maintaining it are concerned. All this may be true in respect of certain other types of engines, operating under conditions dissimilar to those of a railway locomotive, and even with the latter in countries where feed water difficulties arise, but in view of the limited space available and the additional complication involved, condensing cannot be urged as a material or necessarily advisable feature here. Mr. Stanier's design is, as we have already inferred, a very straightforward one, closely allied in some measures with the standards already introduced by him on the London Midland & Scottish Railway. There is a good deal to be said in any case, for proceeding by stages, and it must also be borne in mind that, should it later be considered desirable to convert the locomotive to one of the condensing type, this could very well be done, without any great difficulty, by fitting a condensing tender, as has already been done in some other cases.

It remains to be said that careful inspection of the workmanship put into this locomotive and of the manner in which the components have been assembled show that nothing has been left undone either by the manufacturers of the turbines and transmission mechanism, or by the railway works staff to ensure the success of the design in that respect. The boiler is a very fine piece of work in which, in spite of its large proportions, the weight has been kept down as far as is possible by the employment of 2 % nickel steel plate, whilst welding has been resorted to, in conjunction with riveting, at several points. Efficient water circulation will result from the provision of ample water spaces between the tubes and the boiler barrel, and there is also an abundance of steam space above the water level. Well disposed heating surfaces, the provision of a combustion chamber, special front end arrangements, incorporating a double blast pipe with a double chimney, and adequate grate area, are features calculated to ensure efficient boiler performance. The use of roller bearing axleboxes throughout the engine will do much towards reducing rolling resistance and preventing hot boxes. The cab arrangements are excellent and the enginemen are assured of a good lookout on both sides, whilst the controls, gauges, and other fittings are all easy of access. On this point we can speak with emphasis having put the matter to a first hand test. We congratulate Mr. Stanier on his latest achievement, and it is with a feeling of confidence that we predict a measure of success which will justify the enterprising step he has taken in introducing this new type of locomotive which incidentally marks a

new stage in the locomotive history of this country by the construction of a turbine locomotive in a railway company's works. A fully illustrated description will be found hereafter, accompanied by a folding plate giving detailed drawings of the boiler, turbine machinery, and other principal component parts of the engine.

(Editorial, « The Railway Gazette. »)

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* *

An interesting development in locomotive design is marked by the completion at the Crewe works of the London Midland & Scottish Railway Company of a new 4-6-2 type express passenger locomotive which, in place of the usual 4-cylinder reciprocating type of steam engine, is provided with steam

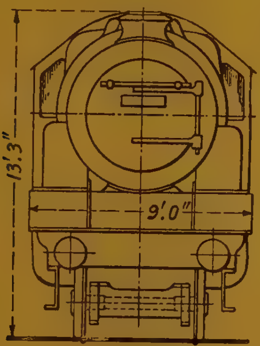


Fig. 1.

turbines and gear transmission to the coupled wheels. It is anticipated that this arrangement will realise a saving of 15 % in coal. In this locomotive, which has been built to designs prepared by Mr. W. A. Stanier, the Chief Mechanical Engineer, the turbine is of the Metropolitan-Vickers, Lysholm-turbomotive type, manufactured by the Metropolitan-Vickers Electrical Co. Ltd. at Trafford Park, Manchester. The turbine is mounted on the locomotive frames which were sent specially to the Trafford Park works for that purpose. The

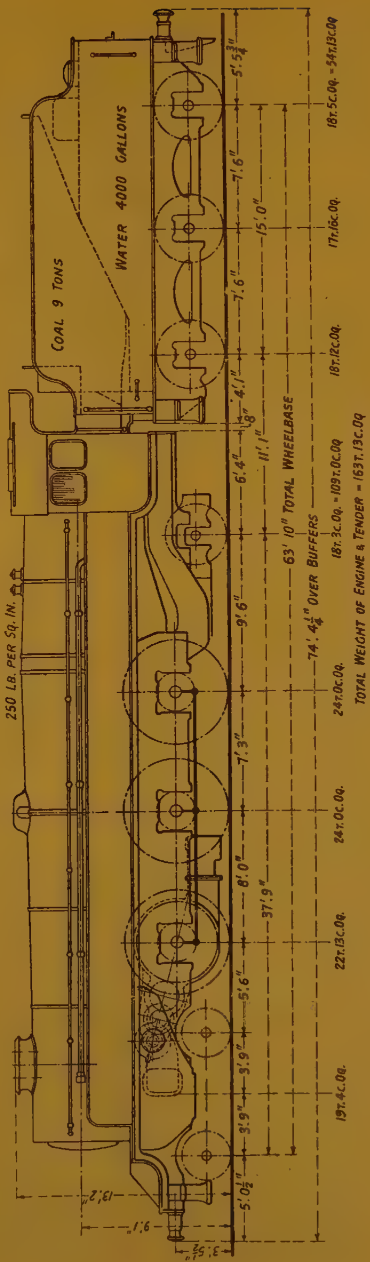


Fig. 2.

locomotive is numbered 6202, and, except for the provision of the turbines and transmission gear, the wheelbase and general appearance are similar to the existing *Princess Royal* and *Princess Elizabeth* engines, built at Crewe Works and put into traffic in 1933. The photographs and drawings reproduced, together with the accompanying particulars, enable the general features of the design to be appreciated.

The provision of a turbine as the prime mover was carefully investigated. Taking into account the fact that the locomotive will be required to work through trains of 500 tons or more between Euston and Glasgow, it was decided that the turbine should be 2 000 H.P. non-condensing, using steam at 250 lb. per sq. inch with a steam temperature of approximately 750° F. The main motive power unit comprises a multi-stage turbine and treble reduction gear, while for reverse running a separate turbine is provided, having an additional single reduction gear, making in all inclusive of reversing, a quadruple reduction gear between the turbine spindle and the driving axle. The turbines, which as intimated above are of the non-condensing type, are bolted to the outside of the side frame plates of the engine with their spindles transverse to the track, the main turbine on the left-hand side and the reverse turbine on the right-hand side. The gear casing is carried between the side frame plates immediately below the boiler.

Main turbine and reduction gear.

In the main turbine the number and type of the stages have been chosen so that a high turbine efficiency is maintained over a wide range of engine speed. Steam from the boiler is led to a steam chest formed as a steel casting containing six control valves which are hand operated from the cab. From the steam chest, the steam passes through flexible pipes to groups of nozzles in the high pressure end of the turbine cylinder, each nozzle group being controlled by one of the six valves. The speed of the turbine, which governs that of the locomotive and train, is controlled by hand from the cab, by opening these control valves progressively, the steam from the turbine exhausting to the atmosphere through the smokebox and chimney in the ordinary manner.

The turbine spindle is directly coupled to the high speed gear pinion, a thoroughly flexible drive being ensured by an intermediate hollow quill shaft fitted with a pair of flexible diaphragm

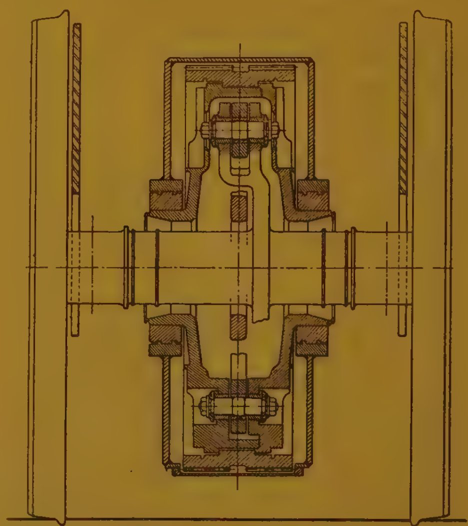


Fig. 3. — Cross section through quill drive on main driving axle.

couplings. The treble reduction gear is of the double helical type completely enclosed in a fabricated gear case, suspended from three supports on the engine frame, and restrained from moving sideways relatively to the turbine. The first and second reduction pinions have been made slightly flexible to equalise the pressure along the teeth.

To take up any relative movement between the engine frame and the driving axle, the final drive from the slow speed gear wheel to the crank arms formed on the main driving axle is a very flexible one. The slow gear wheel encircles this driving axle and is coupled to it by a series of floating links. Leaf springs between the rim and the boss of this slow speed gear wheel prevent transmission of shocks to the high speed gearing.

Reverse turbine and control mechanism.

The reverse turbine is of the impulse type, with, as stated, an additional single reduction gear, the wheel shaft of which is in line with the high-speed pinion of the main gear. For reverse running this wheel shaft of the reverse element is coupled to the main gear by a mechanical clutch operated from the cab. The steam chest for the reverse turbine contains three control valves but in other respects the arrangement is similar to that of the main turbine.

The method of operation of the locomotive differs considerably from the orthodox type, since provision has to be made for reversing by means of a dog clutch situated between the reverse turbine and the final drive. The forward turbine is permanently connected to the locomotive drive, and, when it becomes necessary to reverse, the steam supply to this unit is shut off, and the drive from the reverse turbine engaged by means of a steam operated arrangement. This can be achieved only when the engine is stationary, a safety device being incorporated in the transmission, to prevent the change being made whilst the engine is in motion. When the drive from the reverse turbine has been engaged, the steam supply to this unit can be opened and in view of the fact that, as already mentioned, the forward turbine is permanently in connection with the locomotive drive, this unit must also revolve in the reverse direction when the engine is travelling tender first. Provision is therefore made for a steam feed to the forward turbine during this period to provide the necessary cooling, this being automatically controlled from the reverse gear.

The steam supply to the two turbines is taken first through the main regulator on the boiler (which is kept fully open while the engine is in motion), and then to the regulators on the nozzles of the two turbines, six of which are provided for the forward turbine and half that number for the reverse. These are operated from the control box in the cab, and, by means of suitable interlocking devices between the reversing clutch mechanism and the turbine regulators, it is impossible to admit steam to the forward turbine when the reverse turbine is in gear, or *vice versa.* The fact of the reverse turbine being provided with only three steam nozzles as compared with the six of the main turbine is explained by the fact that the use of this turbine will be necessary only when the engine is running from shed to terminus, shunting for attachment to the train, and such like duties not requiring high power development.

Lubrication of the turbines and transmission.

All the bearings for the turbines and transmission gears, etc., are lubricated by mechanical means from an oil well at the rear end of the gear casing, in which is housed a submerged gear pump. This pump delivers oil at 25 lb. per sq. inch through internal channels to gear-case sprays and the bearings of the turbines and gears. A second pump is carried on the main frames under the footplate and is steam driven, its function being to augment the supply from the gear pump, and also to provide the necessary means for passing the oil through an oil cooler situated between the frames at the front of the locomotive. This pump can be maintained in motion

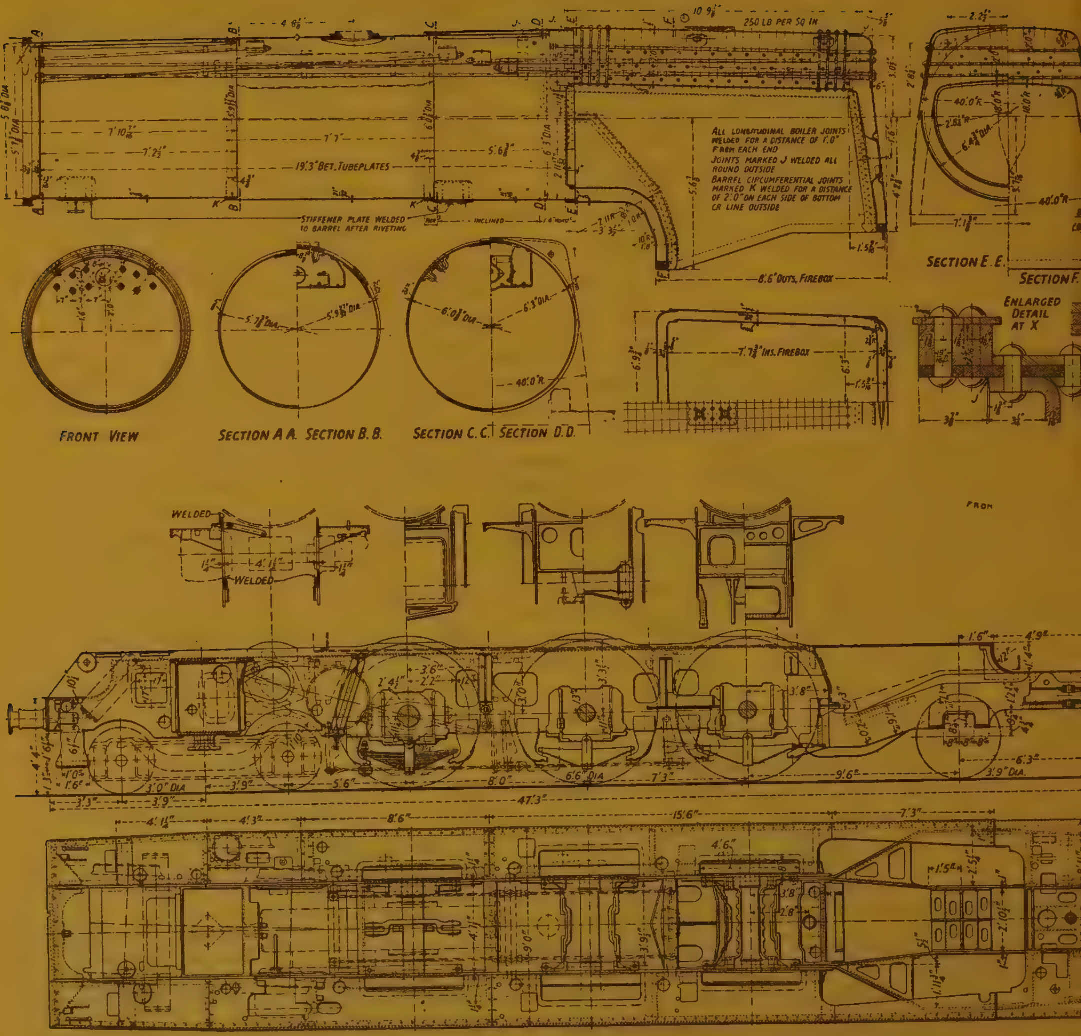


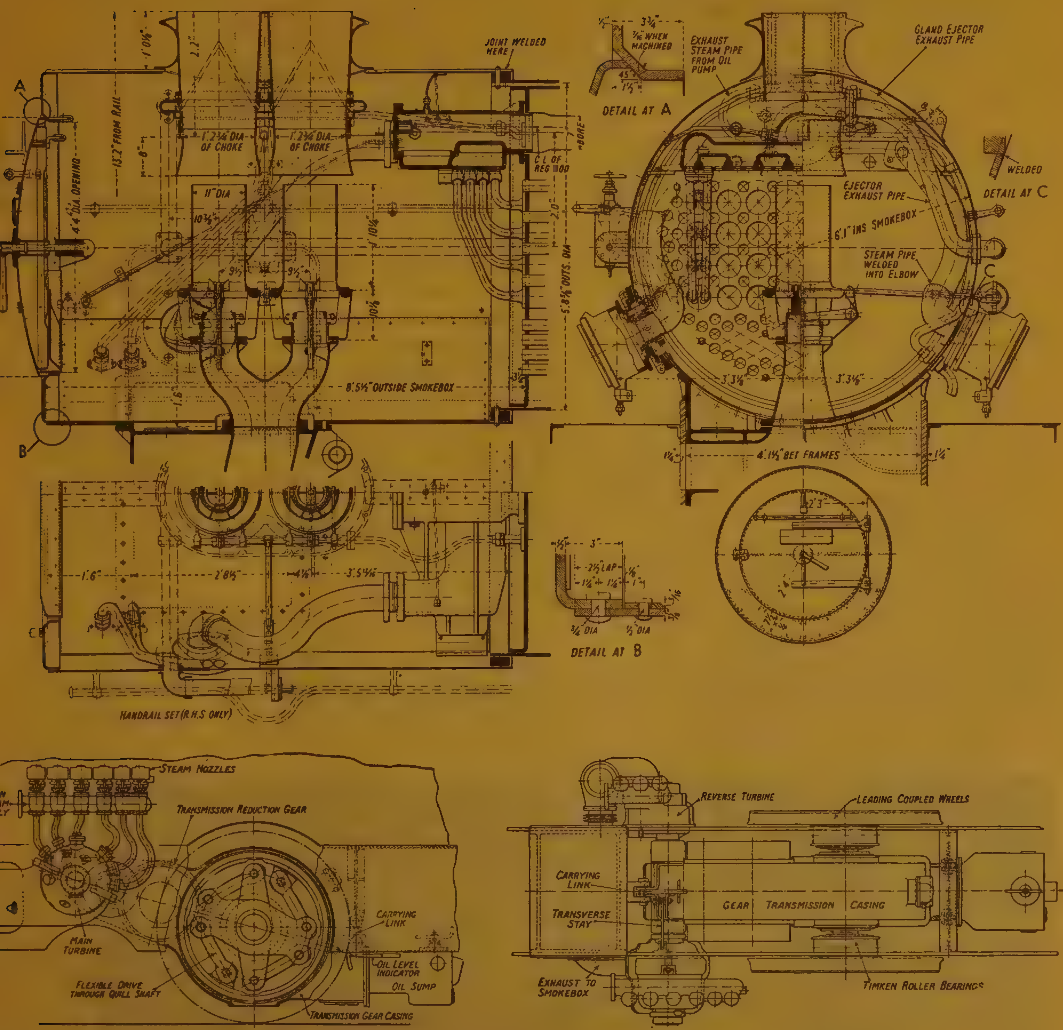
Fig. 4. — Details of boiler and firebox—special smokebox ar

when the engine is standing, the steam supply being controlled from the footplate, and the oil circulation maintained until the engine is again set in motion, when the gear pump automatically comes into operation.

Boiler and firebox details.

The design of the boiler and firebox respectively is shown in the accompanying drawings. The boiler barrel tapers from 6 ft. 3 in. diameter at the throat

By courtesy of the « Railway Gazette ».



—turbines and transmission—and main and subsidiary framing.

plate to 5 ft. 8 5/8 in. diameter at the smokebox tubeplate. A combustion chamber is provided, and this, of course, increases the firebox heating surface. An improvement in combustion is as a consequence anticipated, although the distance between the tubeplates for this boiler barrel is now 19 ft. 3 in. whereas in the *Princess Royal* class the figure is 20 ft. 9 in.

It was very necessary to keep the weight down as far as possible on this

locomotive, and with this end in view the boiler barrel plates and firebox wrapper plates are made of 2 % nickel steel. The smokebox tubeplate is of the drumhead type. The tubing arrangement consists of :

32	steel superheater tubes . .	5 1/8 in. outside diameter.	7 S.W.G.
112	steel boiler tubes	2 1/4 in. outside diameter.	11 S.W.G.

It will be noted that the flue tubes are of steel, the ends at the firebox tubeplate being specially thickened up and screwed 11 threads per inch. The flue tubes and the small boiler tubes are expanded in position and beaded over in the firebox tubeplate. For both superheater and boiler tubes six-roller expanders were used which provide a slight taper in the tube end, the larger diameter being on the water side of the tubeplate. The pitching of the boiler tubes allows for diagonal and vertical bridges of 7/8 inch. Between the tubes and the boiler barrel ample water space has been allowed, providing efficient water circulation.

In addition to the riveted boiler joints welding has been introduced round the seams of the steel wrapper plate and along the longitudinal barrel joints for a distance of 1 foot from each end. The circumferential barrel joints are also welded along the bottom for a distance of 2 feet. Further, the bottom corners at the foundation ring joints, and all pads on the doorplate and boiler barrel for mountings, are welded after riveting. The smokebox tubeplate and firebox doorplate are stayed with the usual type of longitudinal stays.

At the foundation ring the firebox tapers from 6 ft. 10 3/4 in. outside at the front end to 6 ft. 2 7/8 in. outside at the doorplate. This has been specially arranged to facilitate satisfactory hand firing in the back corners. The provision of a large oval fire hole, which is 1 ft. 7 in. wide by 1 ft. 2 in. deep, also helps in this direction. The width of the foundation ring is 3 3/4 inches, and the waterlegs gradually widen to 5 1/2 inches at the top of the firebox to facilitate water circulation. The dimension between the copper crown plate and the steel wrapper plate is 2 feet, to provide ample steam space above the water level. The provision and position of mud plugs and mud doors has received careful attention from the point

Fig. 5. — Engine in the paint shop (main turbine side; part of casing removed).

of view of thoroughly washing out the boiler and firebox.

Boiler staying and mounting.

Monel metal stays 7/8 inches diameter, 11 threads per inch, are provided on the two outer side rows and on the top six rows. On the doorplate the top three rows of stays are copper, 7/8 inches diameter, 11 threads per inch. The other stays are of mild steel 5/8 inches diameter, 11 threads per inch to the following particulars :—

Tensile strength :—32 to 37 tons per sq. inch with an elongation of 28 % to 23 % over a parallel length of 3 inches.

The copper stays are riveted over, both on the outside of the steel plate and on the inside of the copper plate, but for the steel and Monel metal stays a nut is provided on the inside of the copper plate. The stays are caulked both on the steel and cooper plates. Monel metal stays are also used in the curved portions of the throat plate, the remaining stays on the flat portion of the throat plate being of mild steel.

The safety valves, water gauge frames and protectors and other fittings are of the railway company's standard types. There are four pop type safety valves 2 1/2 inches diameter, set at 250 lb. per square inch pressure. As previously stated, 32 flue tubes have been provided in the superheater, the elements (1 1/4 inches o.d. × 13 s.w.g.) of which are of the bifurcated type from single downcomers (1 9/16 inches o.d. × 10 s.w.g.) carrying spherical ball joints to the superheater header. The main steam pipe is of the steam collector and drier type, the inlet being at the highest point of the firebox above the tube plate; the steam being then conveyed along the top of the boiler to the combination regulator and superheater header.

The regulator is incorporated with the superheater header casting inside the smokebox. The control for the main regulator is of the usual type at the firebox doorplate, and to ensure easy manipulation the regulator handle is balanced. A small sight feed lubricator in the cab, under the control of the driver, supplies lubricant to the regulator valve.

Controls for steam supply.

A steam manifold is provided on the top of the firebox doorplate in the cab, and carriers valves for the injectors, ejector, steam brake for the engine and tender, carriage warming, pressure gauge, gear case oil circulating pump, sight feed lubricator to regulator, and whistle.

The steam supply can be shut off by means of a single valve, through which steam is supplied to the manifold. The whistle is placed in a horizontal position to be within the overall height above the rail. The blower valve is fitted on the firebox doorplate on a separate pad below the main regulator, in a convenient position for the enginemen.

Injectors.

The injector on the fireman's side is an exhaust steam injector with 12-mm. cones, and on the driver's side a live steam injector with 13-mm. cones is fitted. The exhaust steam injector feeds through a feed-water heater supplied by steam taken from the forward turbine. Both injectors deliver the feed water to the boiler through top feed clack valves. Sliding trays are fitted underneath the water delivery nozzles inside the boiler to permit periodic cleaning. The driver's brake valve controls simultaneously the application of the steam brake on the engine and the vacuum brake on the train. The valves controlling the supply of steam to the large and small ejectors are incorporated in the same fitting.

The firegate is built up of three rows of cast-iron firebars, the front two rows being sloped and the hind ones level. The ashpan is provided with front,

Fig. 6. — Forward turbine with steam nozzles and piping; left-hand side of engine.

middle and hind damper doors. In addition, side damper doors are fitted between the bottom of the foundation ring and top of the ashpan side, so that sufficient primary air will be available at the sides of the wide firebox. The three main ashpan dampers, front, middle and hind, have separate control handles provided in the cab, and an additional handle is provided to control the side ashpan dampers.

Special smokebox arrangement.

The provision of a turbine in place of the reciprocating power unit has necessitated a considerable modification in the smokebox arrangement, and in view of the low pressure exhaust of the turbine, it was necessary to provide a double exhaust type of blast pipe which, in turn, calls for a double chimney. The blast arrangement is of a variable pattern consisting of a central cone dart which is raised and lowered automatically above the blast pipe cap orifice as the number of steam nozzles for the turbine is increased or decreased. A special type of intermediate petticoat to the blast pipe cap is also used. Special joints at the smokebox side are provided between the steam pipes and the turbine steam chest, to ensure the necessary flexibility for expansion, etc.

The locomotive frames.

The main frames of the engine are of high tensile (35-43 ton) steel, the distance between them is 4 ft. 1 1/2 in., and their thickness 1 1/4 inches. Advantage has been taken of this extra thickness to omit the usual type of horizontal frame cross stretchers, as it is considered that over-staying of the frames laterally is likely to interfere with their flexibility.

In addition to the vertical stretchers provided on the intermediate and trailing coupled wheel axlebox guides, cross stays have been provided to prevent the frames coming in at the bottom which is a common trouble when such large boilers are placed in position. Two separate hind frame plates are provided at each side, and spliced to the main frame, the outer hind frames being splayed outwards and carried through to the hind buffer beam. These frames are 1 inch thick. The inner frames, 1 inch thick, are set slightly inwards to take the centre casting for the trailing two-wheeled truck, and these are also carried through to the hind buffer beam and the main centre drag box casting. Due to the limitations to the depth of frames just below the throat plate of

the firebox, careful scheming was necessary to provide the strength required to resist the heavy stresses imposed when lifting the completed engine. All the rivets at the main frame joint are a turned driving fit and riveted cold, and, in addition, the joint is welded at all the outside edges.

The carriyng of the boiler at the front end of the frames is just behind the smokebox tubeplate, and the second support is between the intermediate and trailing coupled wheels. A gunmetal bearing strip is provided between the bearer and the frame support for the necessary movement due to expansion, and, in addition, clips are fitted at the side.

At the front end of the firebox, the foundation ring is utilised as another sliding support, and on the bottom face of the foundation ring a gunmetal bearing strip is fixed. At the hind end of the firebox, the foundation ring is carried below the plate joints, and a diaphragm consisting of two plates 3/8 inch thick is rigidly attached approximately in a vertical plane to this projection, and the bottom edge of the diaphragm is fixed to the steel casting which forms the dragbox.

Springing and brake gear.

All the laminated bearing springs for the engine and tender are made of silico manganese steel, the plates being of a ribbed section with cotter type fixing in the buckle. The spring links are screwed to permit of adjustment.

The screwed ends of the spring links have a Whitworth thread, and, to provide for the necessary movement at the ends of the springs, the links pass through a shoe which is provided with a gunmetal seating and a spherical washer of steel the surfaces of which are ground. Damper springs consisting of alternate layers of thin steel plate and rubber are also provided between the spring link heads and the frame brackets. The engine is provided with a steam brake which operates at the front of each of the coupled wheels.

Coupled wheels and intermediate drawgear.

All the journals of the coupled wheels are provided with roller bearings supplied by British Timken Limited. Wells are arranged in the underside of the boxes, to supply the necessary lubrication. The intermediate drawgear between the engine and tender is controlled by a laminated spring housed in the tender dragbox. The main drawbar is directly connected to the spring buckle. The side buffing spindles have specially designed heads which ride on case hardened inclined planes riveted to the hind engine buffer beam. The object of this is to obtain smooth riding between the engine and tender.

Leading and trailing trucks.

The wheelbase of the leading bogie is 7 ft. 6 in. and the diameter of the wheels 3 feet. Bar frames are used, and a centre cross casting in which engages the engine bogie pin, also provides the slides. The springs for the bogie bearings are of the inverted laminated type with screw adjustments, the material being similar to the springs for the coupled wheels. Timken roller bearings are fitted to the axlebox journals. Side bolsters transmit the load from the main frames to the bogie. Suitable lubrication is provided for both the bolster and cup and sliding face.

The trailing two-wheeled truck is of the bissel type, and the bogie arm is anchored at a point 6 ft. 10 in. in front of the axle centre to the engine cross stretcher casting immediately in front of the firebox throat plate. The diameter of the wheels is 3 ft. 9 in. on the tread. Timken roller bearings are fitted to the axlebox journals. The transmission of the weight from the main frames

Fig. 7. — Coupled wheel axle with Timken roller bearings.

Fig. 8. — Intermediate and trailing coupled wheels complete.

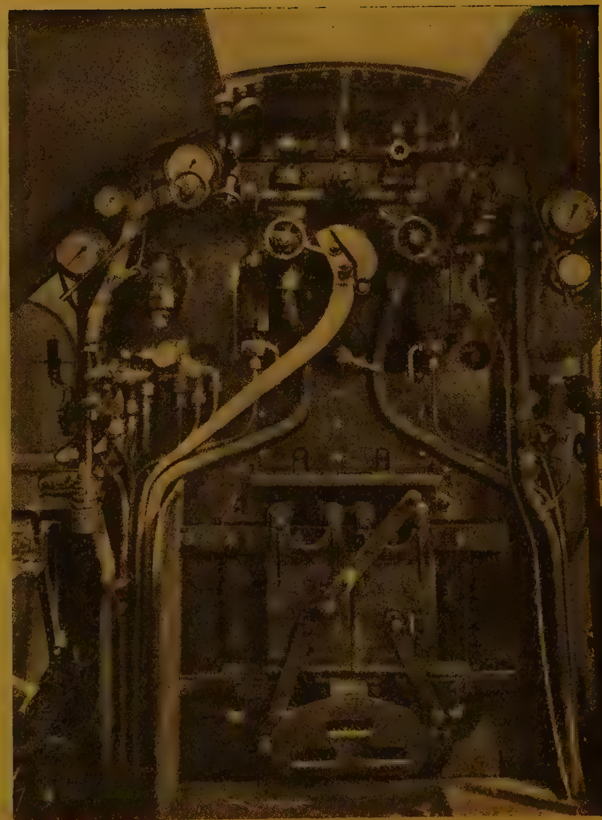


Fig. 9. — Interior of cab showing control, etc., fittings and special fire door.

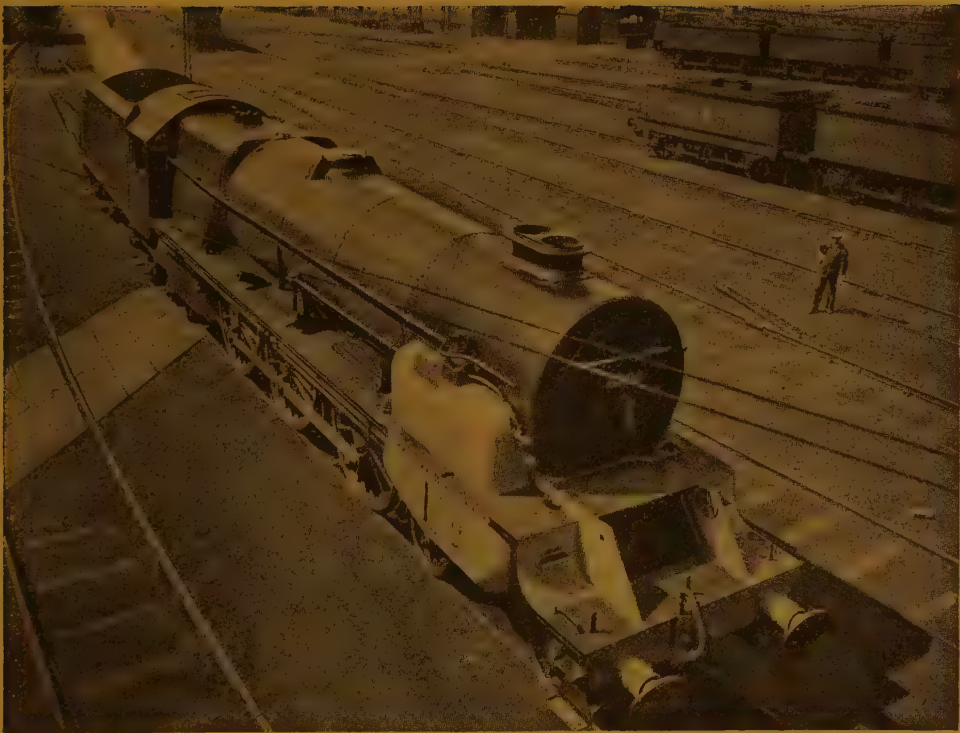


Fig. 10.

to the bogie is, in this case also, by means of side bolsters, but due to the limitation of the design, these are placed inside the bogie wheels.

A higher axle load on this locomotive has been permissible by reason of there being no hammer-blow, the only parts requiring balancing being the coupling rods and crank pins, which being revolving parts are perfectly balanced. The wheel centres are steel castings, and the wheel rim is of a triangular section. The tyres are secured by the Gibson type retaining ring. The balance weights for the coupled wheels are built up by steel plates on both sides of the spokes, and riveted, the requisite weight being provided by filling in between the plates with lead.

Locomotive cab.

Double sliding windows are fitted on both sides of the cab, and on both sides on the outside of the cab and between the sliding windows a small glass screen can be turned into position so that when the enginemen are looking outside the cab it acts as a draught preventer. A hinged window giving ample area for lookout is fitted on each side in the front cab plate. In this plate also a number 1/2-inch holes are provided at the top so that a current of air will pass along the inside of the roof and a sliding ventilator in the cab roof itself should ensure further comfort in this direction. Tip-up seats are fixed on both sides of the cab, and, to prevent

exposure to cold cross winds, gangway doors, spring controlled, are fitted between the engine cab and tender panel plate, rubber extensions being attached at the bottom of the gangway doors.

The sanding is of the mechanical trickle type, the sand being delivered in front of the leading and in front and behind the intermediate coupled wheels. In addition, a water de-sanding apparatus is provided which comes into action simultaneously with the application of sand to the rails, so that after the engine has used the sand the rails are automatically cleaned with hot water to prevent interference with the track circuits.

The standard type of carriage warming apparatus is fitted through from the locomotive to the hind end of the tender, the working pressure being set at 50 lb. per sq. inch. The steam supply is led from a suitable position at the turbine exhaust, but in the event of the exhaust not being in operation, an auxiliary supply of steam is arranged direct from the boiler.

Grease gun lubrication is utilised wherever possible, as, for instance, on the brake gear and intermediate buffing gear.

The tender is carried on six wheels, with a wheelbase of 15 feet, and has a capacity for 4 000 gallons of water and 9 tons of coal. The coal bunker has been designed so that the coal will be self trimming, as far as possible. A door is arranged to give access to the coal space from the engine footplate and there are commodious toolboxes on the tender front. On the left-hand side a cavity is arranged for the accommodation of the firing irons. Hand brake apparatus is fitted to the tender wheels, in addition to the steam brake. Both the water pick-up and tender hand brake handles are arranged vertically, with bevel wheels to transmit the motion to its particular mechanism.

[62. (01, 621. 134.1 & 669]

Stress distribution in aluminium connecting rods,[1]

by R. L. TEMPLIN,

Chief Engineer of tests, Aluminium Research Laboratories, Aluminium Company of America.

(Railway Mechanical Engineer.)

Limitations of available space in the main driving wheels of large freight locomotives frequently preclude the provision of desired amounts of counterbalance weight when using the ordinary types of steel rods. The use of cross-balancing methods, such as that given by Fry (2), may appreciably decrease the dynamic augments resulting from such conditions of underbalance. It would seem, however, that considerably more gain would be made if lighter rods could be used on such locomotives. With lighter-weight rods and lighter counterbalances the out-of-plane forces would also be diminished.

In view of the marked advance which has been made in the development of high-strength light alloys, especially those of aluminum, it would seem that

(1) Abstract of a paper presented before the Railroad Division of the American Society of Mechanical Engineers at the annual meeting, December 4, 1934.

(2) Locomotive Counterbalancing, Lawford H. Fry, *Transactions of A. S. M. E.*, Vol. 56, No. 6, June, 1934, p. 431. Abstract, *Railway Mechanical Engineer*, February, 1934, page 42, and March, 1934, page 79.

a suitable material, for locomotive rods might be found in that field. At the present time one of these alloys is of particular interest because of its mechanical properties and its availability in forgings of sizes suitable for the largest rods. Locomotive rods of this metal have been in use experimentally for a number of years with quite satisfactory results. The metal is designated commercially as 25 S-T and has the following nominal chemical composition :

	Per cent.
Copper	4.4
Silicon	0.8
Manganese	0.75
Aluminum	Remainder.

Extensive tests have been carried out on the metal in the form of large rod forgings and the mechanical properties indicated in Table I obtained. Nine standard test specimens were taken — longitudinal, transverse, parallel and transverse normal to plane of web — each at three locations.

Comparisons of these properties with those of the steels ordinarily used for locomotive rods reveal marked differences which may at first appear disturbing. With a reasonable knowledge of service conditions the magnitude of the stress concentration factors involved and the properties of the newer material, however, rods should be designed which are considerably lighter and yet will give service quite as satisfactory as that obtained from steel rods.

Purpose and scope of investigation.

The purpose of this paper is to describe certain studies and tests that have been made :

(1) to determine the stress concentration factors occurring in models of pin-end members under both tensile and compressive forces;

(2) to evolve a new design of rod end with the intention of eliminating some of the very high stresses;

(3) to confirm the validity of these changes in design by model tests;

(4) to compare the results from some of the models with those obtained from tests of a full-sized rod end, and

(5) to correlate in so far as possible tests made under service conditions with results obtained in the laboratory. The work included laboratory tests of 15 models of pin-end members; tests of a full-size aluminum alloy rod end; tests of a model of the new design of a particular rod end, and field tests of some rods on a large 0-10-0 locomotive under service conditions.

TABLE I.

Mechanical properties of 25S-T locomotive main-rod forgings.

—	Minimum.	General average.
Tensile strength, lb. per sq. in	50 200	55 330
Yield strength, lb. per sq. in.	31 800	35 130
Elongation in 2 in., per cent	8.0	13.7
Endurance limit. lb. per sq. in.	11 500	12 600
Brinell hardness	107	110
Shearing strength, lb. per sq. in.	...	35 000
Young's modulus of elasticity, lb. per sq. in . .	...	10 000 000

In the preliminary tests of 15 models consideration was given to distribution of material around a circular hole; effect of press and loose-pin fits, and shape and types of fillers corresponding to brasses in the wrist-pin end of main rods. Strain measurements were obtained by Huggenberger tensometers by means of which stresses equivalent to about 80 lb. per sq. inch may be observed. In converting strain readings into stress a modulus of elasticity of 10 million lb. per sq. inch was used.

Tests showed, among other things, that the use of loose fitting pins may cause a marked increase in the ratio of the maximum measured to average computed stresses. It may be inferred from what has been pointed out that as wear occurs in locomotive side rod bushings and pins the stresses in the rod ends increase and under some conditions might be expected to become double their initial working value at certain critical locations. It would also appear that more attention should be given to the magnitude of the press-fits used for bushings in side rods. Within certain limits the greater the tolerance used for making a press-fit the less the stress ranges under service conditions. Obviously, there must be a limit to the amount of tolerance allowed in making press fits. So far the tests under discussion have not been extended to define this limit. The results from these model tests, however, indicate that initial stresses set up in full-size locomotive rods using different press-fit tolerances can be determined, as well as the stress ranges caused by the computed working loads. Consideration of these stress ranges and the safe stress ranges obtained from fatigue tests of the material should permit of an intelligent design of rods which would insure safety against fatigue failure.

Test of a full-size locomotive side-rod end.

Aluminum alloy side rods have been used for a number of years on the locomotives of the Alton and Southern. The intermediate rods on one of the engines (No. 13) failed in fatigue after 89 619 miles of service. The fatigue fracture was in a plane normal to the axis of the rod, coinciding approximately with the vertical diameter of the pin and the large grease outlet above it. Since the other end of the rod was similar in design and had a large opening for the main pin, it was decided to use this end for test purposes. The end which

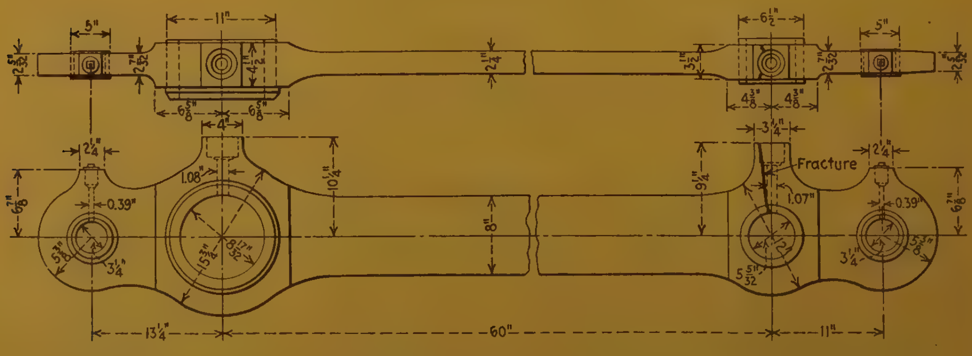


Fig. 1. — Left intermediate side rod of Alton & Southern locomotive No. 13, showing location of failure.

had failed was first cut off, then the shank of the rod machined down so that it would fit in the jaws of the testing machine and a special pin provided with a recess of such size as to give adequate clearance for a Huggenberger tensometer. With this arrangement and an enlarged hole through the bushing in the rod it was possible to measure stresses at the edges of the grease outlet while the whole assembly was under various tensile or compressive loads. In addition, stress measurements were made on the rod at various other locations.

Application of the design loads of 30 000 lb. on the knuckle pin and of 60 000 lb. on the crank pin developed stresses at the knuckle pin up to 7 500 lb. per sq. inch on the outside of the rod and internal stresses at the grease outlet of 14 200 lb. In the reduced section between the knuckle pin and the crank-pin stresses ran up to 3 500 lb. At the crank-pin section stresses ranged up to 5 000 lb. on the outside and up to 9 500 lb. internal at the grease outlet.

It will be noted that the stresses adjacent to the grease outlet were high when compared with other stresses. These maximum measured values, however, do not represent the actual maximum values obtaining, either under the laboratory test loading or under service conditions, because the 1/2-inch gage length of the strain gages used in making the measurements is of the same order of magnitude as the diameter of the grease outlet. The strain measurements obtained with such a gage are, of course, the total strains occurring over the gage length used. In using values obtained with such an instrument the assumption must be made that the stress is uniformly distributed over the gage length. Obviously this is not the case in this particular instance, with the result that the actual stresses at the side of the grease outlet must undoubtedly be considerably higher than those indicated in the tests. Furthermore, the estimated design loads used in determining the laboratory test loads would take no account of stresses caused by dynamic loading nor of those caused by unequal distribution of loads. Such being the case, it is not difficult to understand why the rod suffered a fatigue fracture at the location indicated under service conditions.

In the tests of the full-size rod end, as in the case of some of the models, it was found that the clearance between the pin and bushing had an important effect upon the maximum stresses in the rod. For example, it was found that stresses at the section through the main pin were approximately doubled by removing the support of a close fitting main pin when the load was applied to the knuckle pin. The distortion of the main pin opening, under this loading condition, amounted to only 0.025 inch change in diameter. This value may be compared with the clearances permitted between pins and bushings under service conditions before new pins or bushings are fitted. It is not uncommon to find clearances as much as 3/32 inch between pin and bushing diameter on locomotive rods.

Tests were made to determine the pressure required to push the bushings from the rod, the amount of stress release caused by removal of the bushings and the tolerances provided for making the push fit of the bushings in this particular rod. It took a pressure of 5 400 lb. to push out the knuckle-pin bushing, the tolerance on the bushing being 0.002 inch and the measured stress in the rod 2 300 lb. per sq. inch. To remove the main pin bushing took a pressure of 23 200 lb., the tolerance of the bushing being 0.008 inch and the maximum stress in the rod, 4 400 lb. The stress concentration ratios were undoubtedly influenced by the initial stresses produced by the push fit of the bushings.

From the data obtained in the tests of the full-size rod, it was not possible to determine accurately the maximum stress concentration ratios for the rods without the press-fit bushings. It would seem reasonable to expect, however, that if the load were sufficient to relieve the initial compression in the bushing, the maximum stresses measured would not be appreciably different from those which would have been obtained if there had been no press fit. It the bushing stresses were only partially relieved, the maximum stresses in the rod would be more than equivalent to the load applied on the pin and, therefore, high stress concentration factors would be obtained. The most advantageous press fit, as far as the stresses around the pin are concerned, would appear to be one in which the total compression in the bushing is just relieved by the design load on the pin. Under such a condition the stress range in the rod would be reduced, yet the maximum stress would not greatly exceed that produced without the press fit.

TABLE II.

Summary of tests on model of Alton & Southern intermediate rod.

Loading condition.	Section †	Maximum measured stress, lb. per sq. inch.	Average computed stress, lb. per sq. in.	Ratio maxim. measured stress to average computed stress.
20 000 lb. on knuckle pin without main pin	A-A	17 700	6 570	2.69
	B-B	18 300	4 540	4.03
	C-C	20 000	4 760	4.20
	D-D	...	9 000	...
20 000 lb. on knuckle pin with main pin.	A-A	19 200	6 570	2.92
	B-B	12 400	4 540	2.73
	C-C	8 400	4 760	1.76
	D-D	...	9 000	...
40 000 lb. main pin.	C-C	21 500*	9 525	2.26
	D-D	...	18 000	...
4 000 lb. transverse load on main pin .	B-B	3 800	2 000**	1.90
	C-C	2 800	1 500	1.86
	D-D	16 000	16 600	0.96

† Section A-A is through knuckle pin; B-B through reduced section between knuckle and crank pins; C-C through main pin, and D-D through shank of rod.
* Maximum stress 15 deg. from section C-C.
** Computed bending stresses.

The measured stresses adjacent to the grease outlet for the main pin of the full-size rod indicated clearly that the location of this outlet was unfortunate because of the resulting high stresses. The location was, in fact, probably the worst which could have been selected. When the locations of high stresses resulting from service load are known, it would appear obvious that such places should be avoided when locating grease outlets, keyways, or other openings of similar character. Such openings are bad stress raisers and, when unavoidable, should at least be located in the

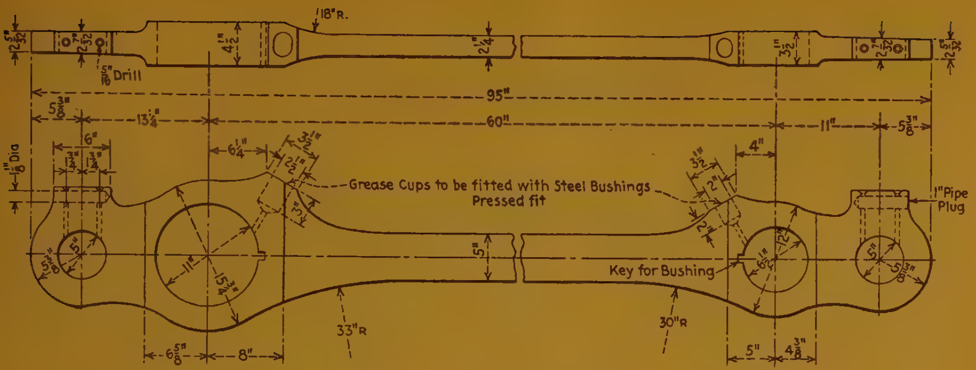


Fig. 2. — New intermediate side rod for Alton & Southern locomotive No. 13.

regions of minimum stress if possible. With these facts in mind a new design was made for a rod to replace the one which failed in service. A new rod is now being made according to this design and will be put into service shortly.

In order to obtain a better idea of what has been accomplished in lowering the stress concentration factors by the new design, a half-size model was made of the larger end of the rod and tested in the laboratories.

TABLE III.

Estimated maximum stresses in new Alton & Southern intermediate rod, based on model tests, compared with similar stresses in older design of rod.

Test.	Loading conditions.	Maximum stresses, lb. per sq. inch.			
		Knuckle pin, section A-A.	Shank, section B-B.	Main pin, section C-C.	Shank, section D-D.
1	30 000 lb. design load on knuckle pin. (Equivalent load on model = 5 900 lb.) . . .	(1)* 5 700 (2) 4 600	3 700 ...	(1) 2 500 (2) less than 25 000	...
1A	Maximum stresses for same loadings on old rod	(1)* 7 500 (2) 13 600	3 500	3 500	...
2	60 000 lb. design load on main pin. (Equivalent load on model = 11 900 lb.) . . .	...	...	(1) 6 400 (2) less than 6 400	5 400
2A	Maximum stresses for same loading on old rod	...	...	(1) 5 000 (2) 9 100	3 300

* (1) Stresses on side of rod.
* (2) Estimated stresses at edge of grease outlet.
Note : Stresses in old rod included stresses produced by the press-fit of the bushings.

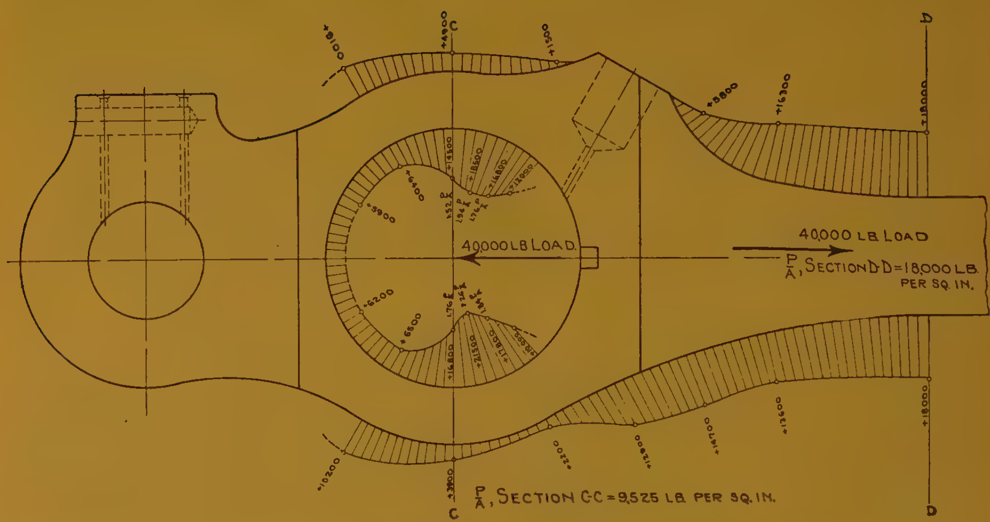


Fig. 3. — Location and extent of measured stresses in a half-size aluminum side rod model with a load of 40 000 lb. on the main pin.

Test of half-size model of new design of side rod.

The new design of rod for Alton and Southern locomotive No. 13 embodied two important changes :

(1) The width of the shank was reduced from 8 inches to 5 inches, effecting a weight saving of about 40 per cent in this part of the rod, and

(2) all grease outlets at the pins were moved from sections of maximum stress to points of comparatively low stress. The half-size model of the new design was loaded successively on both the knuckle pin and the main pin, using loads several times the equivalent of the design values for the full-size rod. The testing procedure was similar to that for the other models tested. In addition, this model was tested as a simple beam in order to simulate the loads in service produced by whipping or vertical inertia forces on the rod. The results obtained are given in table II.

The distrihution of the measured stresses with a load of 40 000 lb. on the main pin are shown also in one of the illustrations.

From the results obtained in these model tests and those obtained on the full-sized rod of the old design an estimate has been made of the probable maximum stresses that will occur in the new rods. These estimated maximum stresses are shown in table III.

Field tests of full-size rods under service conditions.

A few tests under service conditions were made on Alton and Southern locomotive No. 14 during the summer of 1913. These tests were carried out in co-operation with the University of Illinois, the Alton and Southern and the Aluminum Company of America. Data pertaining to this particular locomotive are given in table IV.

TABLE IV.

Specifications of Alton & Southern locomotive No. 14.

Type of locomotive	0-10-0
Cylinder size	28 in. by 30 in.
Steam pressure—nominal	230 lb.
Diameter of drivers	57 in.
Tractive force of locomotive proper	80 500 lb.
Tractive force of booster	15 000 lb.
Weight of engine proper	324 000 lb.
Weight of tender	235 000 lb.
Total weight	559 000 lb.
Run out mileage to Aug. 24, 1933	37 800 miles.
Weight of No. 1 main rod (aluminum)	536 lb.
(steel)	950 lb.
Weight of No. 2 rear rod (aluminum)	144 lb.
(steel)	270 lb.
Weight of No. 3 rear intermediate side rod	
(aluminum)	235 lb.
(steel)	460 lb.
Weight of No. 4 front intermediate side rod	
(aluminum)	415 lb.
(steel)	805 lb.
Weight of No. 5 front side rod (aluminum)	140 lb.
(steel)	266 lb.
Total weight of aluminum rods (one side)	1 470 lb.
Total weight of steel rods (one side)	2 751 lb.
Total weight saved (one side)	1 281 lb.

The dynamometer car (3), jointly owned by the Illinois Central and the University of Illinois, was directly coupled to the tender of the engine and this arrangement used throughout the service test when hauling loads. Complete dynamometer-car records of the usual type were obtained while stresses were measured on each of the main rods of the locomotive and two intermediate rods on opposite sides of the locomotive.

For making strain measurements on the locomotive rods the Baldwin-Southwark-de Forest recording extensometer was used. This instrument consists essentially of a specially cut diamond attached to one set of gage points and a polished stainless steel or chromium plated brass target attached to another set of gage points. In operation a diamond is made to bear against the target and any change in strain in the member under test causes the diamond to scratch a record on the target. The holder in which the target is mounted is pivoted and a spring tends to pull it at right angles to the axis of the instrument, while an adjustable friction brake tends to prevent sidewise movement. When the metal between the gage points is subjected to a change in strain, the friction between the target carrier and the brake is decreased and the target moves sidewise a small amount so that the record is spread out in saw-tooth form. The instrument has no magnification factor other than that obtained from the 3-inch gage length. In order to evaluate the strain from the records it is necessary to photograph the target at magnification of from 100 to 500 diameters. With the strain values and the

(3) University of Illinois Engineering Experiment Station *Bulletin*, No. 43.

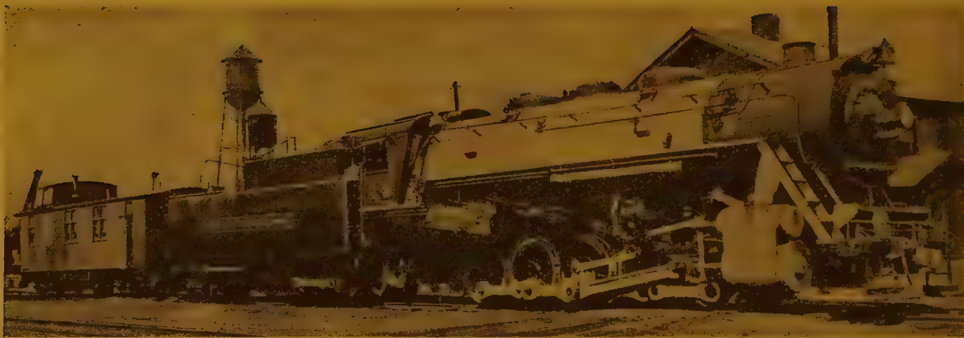


Fig. 4. — Alton & Southern locomotive No. 14 with dynamometer car attached for road test of aluminum rods.

modulus of elasticity of the material the stresses can be readily determined.

The results obtained from the strain measurements together with other pertinent data were summarized. These data indicate that when the locomotive was working at about 80 per cent of its rated tractive force the maximum measured stress in the shank section of the main rods was 7 900 lb. per sq. inch. The stresses in the main rods, however, were fairly uniform over the entire cross-section. One test indicated a slight tendency of the rod to bend toward the outside. The maximum measured stress in the shank section of the rear intermediate rods was 6 800 lb. per sq. inch. This stress was developed when the locomotive was working at about 90 per cent of its rated tractive force. The stress on the inside faces of the rear intermediate rod was about 50 per cent higher than the stresses on the upper and lower edges of the rod, which indicated that the bending stresses were developed in the vertical plane of the rod.

While the grease outlets in these rods are better located than those of the rods from the other Alton and Southern engine, No. 13, previously discussed, yet there would seem to be room for further improvement in the design of the crosshead end of the main rods. In general, the average measured stresses were higher than those computed, which is what might be expected in view of the laboratory tests described. From the stresses measured in the shanks of these rods and the concentration factors found in the laboratory tests, it is believed that a fair estimate can be made at the maximum stresses occurring in the rod unter service conditions. This has been done as shown in table III in the case of the new design of rods for locomotive No. 13.

[621. 33 (.42)]

Southern Railway Electrification to Hastings (England)

(From *Modern Transport.*)

An addition of more than sixty route miles has been made to the electrified section of the Southern Railway on July 7, when public service commenced by electric trains to Lewes, Newhaven, Seaford, Eastbourne, Bexhill, Hastings, and Ore. This new extension increases the route mileage over which electric express trains are operated by more than fifty, and in addition, the electrification of the lines between Brighton and Lewes and between Horsted Keynes and Haywards Heath has been included.

The total single track miles now equipped for electric traction has been increased by more than 129, bringing the total electrified track miles of the Southern Railway to some 1 156, the total route miles being 444. The main lines now electrified are Keymer Junction to Lewes, Lewes to Newhaven and Seaford, Lewes to Polegate and Eastbourne, and Polegate to Hastings and Ore. The electric express trains from London to the principal towns on the new extension operate over lines covered by the extension of January 1, 1933, between the London stations and Keymer Junction, situated between Wivelsfield and Burgess Hill, just south of Haywards Heath.

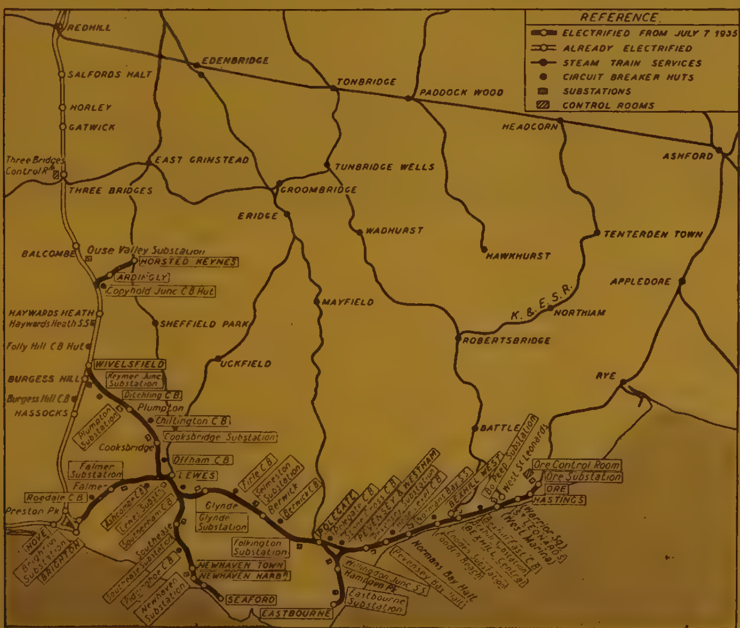


Fig. 1. — Map showing extension of Southern Railway electrification to Eastbourne, Hastings, Horsted Keynes and Seaford.

Outstanding features.

Notable features of this result of the company's enterprising electrification policy are the extensive route mileage which is given an electric service three or four times hourly, representing up to 100 % increase in train service between Brighton and Hastings, and 66 % between London, Lewes and Hastings; the introduction of two-coach train units for local and semi-fast work on both the Hastings and Eastbourne and the existing Brighton-West Worthing electric services; and the provision of Southern Railway buffet cars worked by the Pullman Car Company's staff on the second sections of twelve-coach trains. This also applies to trains on the Brighton and Worthing services, the new stock being available for this purpose, while Pullman cars are provided to Eastbourne in train sets built for the Brighton service opened in 1933.

Power supply and distribution.

Electrical energy for the extension is obtained from the Central Electricity Board's grid, as has been the case in all recent extensions of the Southern Railway electrification. Additional feeding points have been established via the Central Electricity Board's substations at Eastbourne and Hastings, and the railway company has laid an E. H. T. cable between these two points, and also between Eastbourne and a tee off the railway's feeder cable between Three Bridges and Brighton Central Electricity Board substations. In this way supplies already established for the Brighton extension are made use of for the new extension, and what is virtually a ring main has been obtained. The high tension and pilot cable runs are similar in construction to those on the Brighton extension.

Following the railway's recent practice the E. H. T. cable is looped into and out of the railway substations on its course, tee-off connections being made to those not on the main route of the cable. The energy is supplied at 33 000 volts, 50 cycles, and is distributed at this pressure to each of the substations, where it is converted to direct current at 660 volts for supply to the conductor rails. At Southerham Junction Bridge, near Lewes, the cables are contained in ducts buried in concrete four feet below the bed of the river. This has been necessary as the bridge has to be opened periodically for shipping.

Each substation is provided with a 2 500-kw. mercury arc rectifier equipment. Substations are identical as regards equipment and almost so in the matter of layout, the latter being determined to some extent by site requirements. In all, sixteen substations and fourteen track paralleling huts have been erected, the general design being similar to that adopted on the Brighton and Sevenoaks extensions. Each substation consists of two sections, one comprising the E. H. T. switchgear and the other the rectifying equipment and the auxiliary switchgear. The E. H. T. switchgear is supported on reinforced concrete structures. Each of the incoming E.H.T. feeders is connected to an oil switch of a rupturing capacity of half a million k.v.a., which is connected to the opposite ends of a short busbar from which a tee-off connection is taken through a similar oil switch to a main oil-cooled transformer.

The 33-k.v. supply is stepped down by this transformer into a double six-phase supply, at the voltage required at the anodes of the rectifier. Current for signalling, lighting and other substation auxiliaries is obtained by means of single-phase 20-k.v.a. transformers, one of which is connected direct to each of the two incoming feeders. Electrical energy for the rectifier and other substation auxiliaries is obtained from a three-

Fig. 2. — E. H. T. switchgear and auxiliary transformer, Newhaven.

phase 30-k.v.a. transformer which is connected to the same tee-off point from which the main supply is taken to the rectifier.

Falmer substation.

In addition to the two standard incoming feeder equipments, two outgoing E. H. T. switchgear equipments have been provided at Lewes substation, for the control of one feeder to Falmer substation and another to Southease and Newhaven substations. Falmer substation is provided only with the oil switch equipment necessary for the control of the main supply to the rectifier, so that a very compact design of substation has been obtained. Arrangements have been made, however, at this substation for expansion of the E. H. T. switchgear on standardised lines, if and when it becomes necessary. The arrangements for the remainder of the equipment at this substation are standard.

The mercury arc rectifiers are duplicates of those installed on the Brighton, West Worthing and Sevenoaks extensions; each has a continuous capacity

of 2 500 kw., corresponding to 3 790 amperes on the direct current side. Greater currents can be given for correspondingly shorter times. The rectifiers are water cooled by means of a closed circuit, thermostatically controlled. The local control of the E. H. T. switchgear, rectifier and auxiliaries is contained

Fig. 3. — 2 500-kw. mercury arc rectifier and transformer, with negative busbar equipment on left of photograph.

within a cabinet faced by a flush type switchboard. This switchboard is divided into three panels, arranged for the control of the E. H. T. switchgear, the rectifier, and the auxiliary services.

The positive lead from the rectifier is taken through a main high-speed circuit-breaker of a continuous carrying capacity of 4 000 amperes to a busbar from which connection is made to the track feeders through smaller high-speed circuit-breakers. Each circuit-breaker is provided with isolators so that it can be taken out of circuit when necessary without disturbing the supply of the remaining units. The local control equipment for each track feeder circuit-breaker is mounted on a panel placed below the shelf carrying the track feeder breakers. Feeder cables connected to

Fig. 4. — General view of Falmer substation with switchgear arrangement for single incoming E. H. T. feeder.

the track rails return the current to the negative busbar which is in turn connected to the neutral point of the main transformer through the absorption choke coils.

Supervisory control extended.

The whole of the electrical equipment in the substations is arranged for remote operation by supervisory control, the positions of the circuit-breakers in the track paralleling huts being also indicated by the same system on the control panels situated at Three Bridges, where provision for extension was made at the time of the Brighton electrification, and at the new Ore control room.

The Three Bridges control room has been provided with additional equipment to extend its control over the substations and track paralleling huts in the new area as far as Eastbourne and Seaford. The new panels, which are exactly similar in appearance and design to those erected for the Brighton and West Worthing section, are arranged along the straight wall of this control room, from which 29 substations are now operated. A new control house,

similar in design to that erected at Swanley for the Sevenoaks extension, has been erected at Ore for the control of the substations and track paralleling huts on the section between Polegate and Willingdon Junctions and Ore. The panels at Ore are arranged along the curved wall, leaving ample space for future extensions.

By means of mimic busbars and switch units, the whole of the main power circuits for the supply of energy to the conductor rails is represented on the main control board in the control rooms. Each switch unit represents an oil switch or a D. C. circuit breaker, and consists of a red, green and white lamp and two operating keys.

Remote substation operation.

The procedure adopted to operate a switch in a distant substation is as follows : The key marked « call » of the selected switch unit is first depressed, and releases a contact arm which rotates over a segmented face plate situated in a transmitter cabinet. Simultaneously a similar arm rotates step by step synchronously over a similar face plate in the distant substation. If everything is in order when the arm reaches the position corresponding to the particular « call » key depressed, it stops and a white lamp on the switch unit glows to indicate that this part of the operation has been satisfactorily carried out. At the same time the selector arm in the distant substation stops. Should, however, for any reason, the arm occupy a position which does not exactly correspond with the arm in the transmitter cabinet, the two arms are resynchronised automatically.

A single white lamp mounted on the centre of the substation panel remains dark while resynchronising takes place, and no operation whatever can be carried out from the panel until normal conditions are restored. With normal operation of the selector this particular white lamp glows steadily, flashing intermittently while the selector is moving from one position to another. The distant oil switch or circuit-breaker having been satisfactorily « called », it may now be operated by the agency of a second key. Satisfactory operation is indicated by red and green lamps which indicate the closed or open position of the switch.

In a case of E. H. T. feeder oil switches an additional orange lamp is provided by means of which the difference of the frequency of the supplies on the two sides of the switch is made visible, before the operation of closing. The lamp glows steadily when the two supplies are in frequency and at other times will blink at a rate depending on the difference of the two frequencies. All that is necessary to put a substation into commission is to close the oil switch controlling the rectifier transformer. Other auxiliary equipment at the distant substation comes automatically into action and is so interlocked that faulty operation of the substations is obviated.

Distant instrument readings.

Load conditions at the distant substation may be observed by indicating instruments which are connected in circuit when a special key marked « meters » is operated. Readings to these instruments are transmitted through the selector system by means of a balanced beam potentiometer system. All the oil switches and direct current circuit-breakers in the substations are provided with protective arrangements. When one of these switches automatically trips the fact is signalled to the control room by the ringing of a bell and the flashing of a clear lamp at the top of the panel representing the substation in which the particular switch is situated. These conditions persist until the attendant has operated a resetting key. The attendant first proceeds to discover which of the

switches has automatically tripped, and this is done by means of a « check » key. The operation of this key causes the selector arms to rotate and to connect in succession each one of the switches to their appropriate indicating units. When the selector passes over the contacts corresponding to the switch in question the indicating signal lamps will change over from red to green and the attendant then either recloses the switch or confirms its new position, either of which operations will clear the signalled fault.

The rectifier direct-current circuit-breakers and the circuit-breakers provided in the track paralleling huts are entirely automatic in action, and when one of these switches automatically trips the fault indication is removed as soon as the indication on the control board corresponds with the position of the switch. This will occur as soon as the selector arm passes through the position occupied by the contacts of the switch during the « check » operation.

In order to inform the staff at Three Bridges and Ore control rooms of the exact conditions of the supply to their respective areas, the E. H. T. feeder oil switches at Eastbourne controlling the supply to the railway company, together with certain switches in Willingdon Junction substation, are indicated at both control rooms. Operation of these switches, however, is only effected from one control point. A telephone exchange to all substations and track paralleling huts is accommodated in a desk which is located at the centre of the floor in each control room.

Control room batteries.

A system of « calling » keys and meters for testing the supervisory pilot wires is also mounted on the desk. The control system is fed through two 250-ampere-hour 120-volt centre-tapped secondary batteries at the control room and from similar batteries of 50 ampere-hour capacity in the distant substations. The substation batteries are normally trickle charged through metal rectifiers, arrangements being made to give full charge if necessary. The control room batteries are charged by duplicate motor generators. One of these machines is driven by a D.C. motor for which a source of supply at 660 volts is obtained from the conductor rails; the other motor generator is driven by a three-phase motor for which the energy is obtained from the auxiliary A.C. supply in the adjacent substation. These batteries are charged through an unusually comprehensive equipment, the whole of which is contained within cubicles bolted together to form a complete unit. This equipment is automatic in action and is arranged to maintain the supply of energy to the control boards and supervisory system should either or both of the sources of supply fail.

Under normal conditions one generator supplies the energy for the control board and trickle charges one battery, the remaining battery acting as a standby. Should, however, the supply for the motor-generator fail, the motor-generator connected to the other source of supply starts up automatically to carry on the service of the previous generator. If, for any reason, both supplies fail, then both batteries are automatically paralleled together to supply the supervisory requirements, and when either or both of the supplies is restored the corresponding motor-generator starts up and proceeds to charge both batteries.

When the batteries are fully charged one battery is put on trickle charge and the other is kept as a standby as in the conditions before the interruption. The particular motor-generator set which it is desired should be running normally is selected by means of a key mounted on the battery charging switch board. Energy for the normal lighting of the control rooms is obtained

Figs. 5 to 7. — Control room equipment.

Fig. 5. — The Lewes substation panel at Three Bridges control room.

Fig. 6. — Transmitter cabinet of supervisory control, Three Bridges.

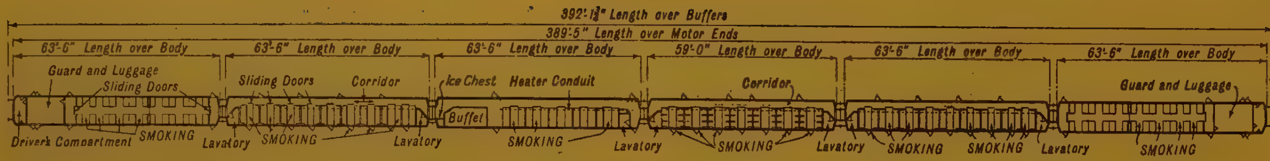
Fig. 7. — Control board for the Hastings-Polegate section at the new Ore control room.

from an auxiliary A.C. supply from the adjacent substation. A small amount of current for emergency lighting is taken from the batteries, should the normal supply fail.

Track equipment.

The conductor rails on the new works are of the Southern Railway standard type and weigh 100 lb. per yard. They are supported on porcelain insulators, for which generally about 620 per mile are used. The rails are normally in 60-foot lengths and are bonded together by four copper bonds having a total cross sectional area of 1.6 sq. inch. The negative traction circuit is provided by the running rails, which are bonded together for this purpose at each rail joint by two protected type copper bonds whose aggregate cross sectional area is 0.332 sq. inch. Stranded bonds are used on points and crossings and also to form cross bonds between the running lines. In certain cases negative cable is used also for this purpose. Sections of the conductor rail are isolated by means of hook switches which are provided between the feeders and the conductor rails. These switches are operated by wooden poles kept at strategic points and are worked to the instructions of the control room supervising the area.

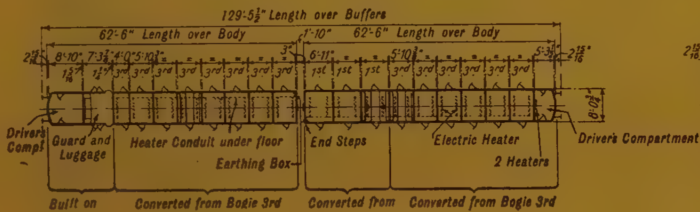
Groups of high-speed circuit-breakers are installed in small buildings at the side of the line, at points which are half-way between the substations. These



Motor 3rd brake.	Corridor 3rd.	Corridor 1st buffet.	Corridor 1st.	Corridor 3rd.	Motor 3rd brake.
Seating capacity :	Seating capacity :	Seating capacity :	Seating capacity :	Seating capacity :	Seating capacity :
Third class 52 seats.	Third class 68 seats.	First class 30 seats.	First class 42 seats.	Third class 68 seats.	Third class 52 seats.

Total seating capacity : { First class 72 seats. Third class 240 seats. } 312 seats.

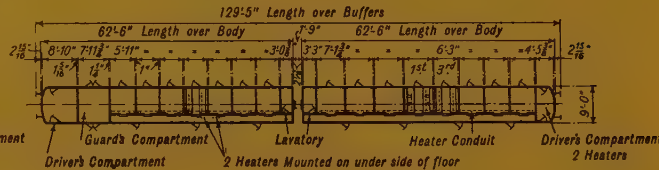
Fig. 5. — Plan showing arrangement and principal dimensions of the new six-coach buffet-car express train units used on the Eastbourne and Hastings services, and in conjunction with existing Brighton and Worthing express units.



Motor 3rd brake.
Seating capacity :
Third class 75 seats.

Driving trailer composite.
Seating capacity :
First class . . 24 seats.
Third class . . 60 seats.

Total seating capacity : { First class . . 24 seats. Third class . . 135 seats. } 159 seats.



Motor lavatory 3rd brake.
Seating capacity :
Third class . . 56 seats.

Driving trailer lavatory composite.
Seating capacity :
First class . . . . 24 seats.
Third class . . . . 32 seats.

Total seating capacity : { First class . . 24 seats. Third class . . 88 seats. } 112 seats.

Fig. 6. — Arrangement of (left) local service two-coach converted steam compartment stock unit, and (right) new corridor non-vestibuled set for semi-fast service to Eastbourne and Hastings.

equipments are known as the track paralleling and are provided to take advantage of all the cross-sectional area of the conductor rails, while giving sectional protection and isolation facilities between the substations.

New rolling stock.

The rolling stock for the passenger services on the extension is of three kinds, all of which, it is understood, is also operated on the existing Brighton and Worthing electric services :

a) For the local stopping services, two-car motor units of non-corridor stock 8 ft. 0 3/4 in. wide.

b) For the semi-fast services from London, two-car motor units of corridor stock 9 ft. 0 in. wide.

c) For the fast services from London, six-car motor units of corridor vestibuled stock 9 ft. 0 in. wide.

The passenger accommodation and leading dimensions of the various units are shown in the drawings figs. 7 to 9.

Local service sets.

The two-car non-corridor units for local services consist of one motor car and one driving trailer car, and 33 such units have been provided for the new local services between Horsted Keynes, Brighton, Seaford and Hastings, while 17 others will be available for the Brigh-

Fig. 10. — Six-coach buffet car express train on the Eastbourne and Hastings section.

ton-West Worthing services. They have been constructed in the company's workshops by the conversion of steam stock bodies, mainly of former London and South Western Railway design, to suit electrical working and have been mounted on new underframes and bogies. The units are equipped with standard Southern Railway suburban stock electric traction equipment. Compartment heating has been improved by the use of a new tubular type heater, two of which are provided to a compartment. The heaters are arranged so that one or both may be on.

Semi-fast train stock.

The two-car corridor sets for semi-fast trains consist of one motor car and one driving trailer car. Ten units have been built by the Southern Railway and they are new throughout. Each coach of the unit is provided with a corridor but there is no vestibule connection between the cars. The electric traction equipment is similar to that of the two-car non-corridor units for the local services, as is the lighting and heating equipment, and the coaches, like the local trains, are mounted on standard suburban trai-

Fig. 11. — The new buffet cars have pantry accommodation (on left), and first-class compartments (on right). Ventilators are of the « M. M. Airstream » type.

ler bogies with one motor bogie per motor car, each motor bogie carrying two totally enclosed 275-H.P. motors. A constant supply of hot water is provided for each wash basin in the lavatory compartment on each car from an electrically-heated thermostatically-controlled storage heater.

The six-car corridor units for the fast services are formed of two corridor saloon type motor cars, between which are coupled two corridor third-class cars, one corridor first-class car and one corridor buffet car. The vestibule connections between the cars afford continuous communication. Seventeen such units have been provided for this extension and they are new throughout, the trailer cars having been built by the Southern Railway and the 34 motor cars by contractors, this order being divided equally between the Birmingham Railway Carriage and Wagon Co., Limited, and Metropolitan-Cammell Carriage and Wagon Co., Limited.

The electric traction equipments are similar to those of the express stock in operation on the Brighton line, with electro-pneumatic control gear mounted on the underframes and two totally enclosed 225-H.P. motors mounted on each motor bogie, there being two such bogies

Fig. 12. — One of ten new two-coach corridor non-vestibuled electric train sets for semi-fast service, Eastbourne and Hastings electrification.

to each motor car. The trailer bogies are of standard suburban pattern in this rolling stock, while for the motor bogies the design is similar to that of the Brighton stock.

The buffet, or pantry, cars are quite new in conception and are intended to offer refreshment facilities both to the first-class compartments which occupy the remainder of the vehicle and to other third and first-class compartments through the train. The cars are worked by the staff of the Pullman Car Co., Limited, and a number of trains daily will have this form of accommodation only. The layout of the buffet section, which has a serving hatch at each end, is indicated on the drawing.

Draughtless ventilation.

Improved ventilation has been incorporated in the buffet cars and also in the saloon motor coaches, with a view to the elimination of draughts. The side windows are not made to open, and instead communication with the out-

Fig. 13. — 33 two-coach sets of converted steam stock have been provided for local services between Horsted Keynes, Seaford, Brighton and Hastings.

side air is given by specially designed « MM. Airstream » ventilators constructed by Mead, McLean and Co., Limited. This device is fixed in two movable frames above each large window and consists of a concave glass deflector close to the fixed panel. A stream of fresh air is guided along the inside of the deflector by the forward motion of the train and the major portion of the stream escapes through the rear opening. A certain amount of newly introduced air, however, remains in the carriage and displaces the vitiated air through the rear opening. Through the combined action of the fresh air stream and the escaping used air, outside currents cannot penetrate past the rear edge, and draughts are prevented.

Frameless windows.

Where possible, the windows in the new rolling stock are of the frameless type, which has been the subject of experiments on British railways over a number of years, owing to its refined appearance and the increased amount of light admitted compared with the wood-framed window. In every case hitherto this type of window has been rejected owing to the difficulty experienced in preventing rain and moisture, due to inside condensation, from attacking the wood or metal inside panels and rails, and also the balancing mechanism, which caused considerable damage and required constant repair.

On the new Southern coaches the problem appears to have been overcome by the drainage system incorporated in the Beclawat « weatherproof » window, which is of the balanced type and is locked in any position by a central lever recessed into the inside garnish rail. This lever, when pulled into the locked position, first actuates a rubber faced hinged capping, to press the glass evenly against an outside rubber moulding, and then operates ramps on the side pillars which press the glass against the outside wall of the glass run, effectively sealing the interior from draught. Two troughs are situated one on each side of the channel holding the bottom edge of the glass and are integral with it. Any water which runs down the inside or outside face of the glass past the rubber on the waistrail, enters the troughs and is then carried down side channels, through drain-holes, to the exterior. Water running down the side glass runs is similarly dealt with, great care having been taken that no part of the actual carriage construction allows moisture below the waist.

Train services.

As on previous electrification extensions, regular headway services are being provided, approximately hourly by express trains from London to Hastings viâ Eastbourne, calling at Haywards Heath and Lewes, and four daily semi-fast trains which make additional stops. The service is in operation from Victoria from 8.45 a.m. to 12.0 midnight, and 22 trains have an average journey time of 86 3/4 min. as compared with 16 fast trains averaging 98 1/2 min. under steam working. The usual electric express time is 84 min., but the 5.4 p.m. from London Bridge and the 5.20 p.m. from Victoria occupy 80 minutes for the 65 3/4 miles, with a stop at Lewes, where the rear portion is detached to work through to Seaford. In the case of twelve-coach Eastbourne and Hastings trains the pantry car section is left at Eastbourne, and the section containing the Pullman car proceeds to Hastings. An hourly service is provided from Horsted Keynes to Haywards Heath, Lewes and Seaford; two trains hourly work from Brighton viâ Lewes to Seaford; and two local trains hourly connect Brighton and Hastings viâ Lewes and Eastbourne—a coastal train service of unequalled intensity.

[625. 213]

The suspension of high-speed self-driven and electric railcars,

by AD. M. HUG, M. I. Mech. E.,
Consulting Engineer, Thalwil (Zurich).

Many builders without previous experience in designing bogies for motor units have been forced to tackle this problem when designing and building railcars for high service speeds.

Ignoring the experience obtained with electric traction where the problems to be solved were actually the same, certain firms thought it advisable to introduce new designs, the results of which in some cases were satisfactory when the stock was new, but were quite otherwise after a short time.

Certain builders, for example, questioned the advisability of fitting bolsters to railcar bogies.

By extension, the same question was raised when designing modern electric motor coaches in order to make them as light and fast as railcars; also in connection with the bogies of certain trailer vehicles which, instead of being hauled as is usual in steam trains, may normally be pushed when worked in train sets with an electric motor vehicle at one end.

In many cases too, the necessity of making vehicles to the largest possible cross section pass through a given loading gauge in international traffic, has led to a notable reduction in the body side movement, and consequently that of the bogie bolster.

Is a limited side movement compatible with the work the bogies of railcars, electric motor coaches, or trailers marshalled in multiple unit sets, have to do? By means of this limited bolster side movement alone and if no help can be expected from the couplings in steadying the vehicle, can the bogie bolster be prevented from striking the bogie frame and cause shocks so unpleasant for the passengers, apart from any ill effects on the stock and the track? Or must we use one or other of the solutions proposed as a substitute for the bogie bolster?

Shall we end, for example, by using bogies with the centre carried on bogie cross bearers? The whole of the spring gear would then have to be fitted between the bogie frame and the axle boxes.

Or shall we come to the use of bogies with the centre carried on a floating bolster — as frequently used on goods stock — with almost no side play between this bolster and the bogie frame, stop blocks being used for this purpose? The drawback of this design would be that as soon as the guides are worn and the play becomes appreciable, the bolster would tend to oscillate on its springs — or the latter on their seats when elliptical springs are used — as much or even more on the straight than on curves because of irregularities in the rail surface. The bolster would then come into contact with the frame and cause the shocks which should be prevented by all means.

Another drawback, common to these two designs, is that all horizontal movements imparted to the bogie frame in running are transmitted directly to the centre and set up a high-frequency wave motion felt in the body as a « shimmy » effect.

To avoid this defect, it has been suggested to connect the body to the frame of each bogie in the horizontal plane, as for instance by an elastic device of variable resistance.

This increases the mass depending on such movements to which the bogie alone is usually subjected directly, and the period of these movements is lengthened at the same time. The movement of the centre pin and that of the body is then converted into a hunting movement, similar to that experienced with four-wheeled vehicles, in which the body is connected with the wheels through the axle guards and without being free to move independently, so that it shares all movements of the wheel sets in the horizontal plane.

In bogie carriages carried on bolsters (a method which would appear the proper one for use on bogie motor vehicles) and even when the side movement of the bolster is restricted to a very small amount, the swing links carrying the bolster allow the body, through its inertia, to move along a straight-line path, whilst the geometrical centre of the bogie frame moves to one or other side of the centre line of the track.

Then too, these swing links tend to increase the side movements of the body so that for the sake of the passengers' comfort this tendency should be restrained as far as possible by damping devices.

These conclusions, although too often forgotten, are those Marié [1] put forward in his classic work. He showed that a vehicle is *stable* on a given track at a given speed when it offers great resistance to derailment and to overturning, and is *comfortable* when the various oscillations of its spring-borne weight only result in reasonable accelerations and do not persist in the passenger compartments.

[1] Georges Marié : « Traité de stabilité du matériel des Chemins de fer » (*Treatise on the stability of railway rolling stock*). (Béranger, Paris and Liége, 1924.)

Marié made it clear he referred to oscillations in all directions, vertical as well as longitudinal, and especially in the lateral direction in which real shocks are often experienced, which then result in the oscillations being considerably accelerated.

He also pointed out, in connection with lateral oscillations, that hunting, for example, sets up rolling which at the position occupied by the passengers is of considerable magnitude; that, furthermore, the lateral shock can be very severe if not damped out, and that in this case the lateral oscillations are suddenly checked, so that the pressure of the various parts on each other can be considerable (and comfort primarily consists in seeing that the human body is not subjected to severe reactions); and that therefore the stock must have some elasticity in the horizontal plane, as is also necessary for preventing derailments.

Marié also stressed the necessity for providing appreciable resistance to lateral movement, and to introduce in the stock considerable damping friction to *absorb any resonance set up by hunting oscillations.*

He showed that, on the bogie boster striking the bogie frame, the oscillations of the body about a centre line parallel to the rails through the imaginary point of projection of the swing links is stopped, and that from this moment the body oscillates, with an ordinary rolling motion, about a lower centre line of oscillation.

Whilst he showed that road motor cars are protected by skidding against horizontal reactions, he stressed the fact that in the case of railway rolling stock, in order to get satisfactory stability, bogies with great frictional resistance to lateral movement were an advantage,

adding that such bogies would *be essential when the speeds* usual at the time he wrote, *would be much exceeded.*

It is a remarkable fact that the accuracy of MARIÉ's conclusions has been proved quite empirically by « The J. G. Brill Company », the first American firm expert in the design and construction of electric motor coaches, and then of all kinds of railcars. This Company, for instance, a long time ago incorporated, in its bogie designs, devices to damp out the side movements of the bogie bolsters.

For this reason (2), in those of its bogies in which the load on the centre was transferred to the solebars near the axle boxes by hangers secured to the sole bars, these hangers were carried on large diameter seats forged solid on the top of the solebars.

In order to improve the springing in the horizontal plane of the bogies in which the elliptical springs carrying the body bolster are supported by a bolster carried by the bogie middle bearers, a patent was taken out in 1913 to cover the application to the lower pins of the bottom swing links, of coiled springs able to develop considerable pressure, and intended to damp out the side movement of the bogie bolster by friction.

The first of these two mentioned arrangements, although simple and without any means of adjusting the braking effort, nonetheless already gave very interesting results, even though coiled springs were used in the spring hangers, which springs formed one stage of the spring gear, but had the disadvantage of causing body roll.

The second arrangement, which is improved so as to be adjustable, is the one the Brill Companies still use to-day, either in the original form or in improved patented forms specially used on bogies in which the side movement is damped by friction due to contact between the hangers and the enlargements of the solebars on which they were carried.

The results due to these spring dampers, the simplest design imaginable, are definitely satisfactory. The fact has been proved many times by the thousands of bogies so fitted. Other devices for damping out the side movement of the bolsters are furthermore available, and have been applied in service.

However, the use of these dampers is not without undesirable features, especially in stock in services requiring heavy braking efforts, which would be the case when bogies with limited bolster side movement were used. These dampers in the bolster suspension increase the tendency of the body bolster secured to the body, and the bogie bolster carrying the springs supporting the body bolster — bogie bolster on which the braking action of the damping device acts directly — to move transversely relatively one to the other.

This relative displacement of the body bolster and the bogie bolster is due to the springs carrying the bogie bolster tilting, and this tilting can cause the body to move sideways, the very thing which is to be prevented.

To meet this drawback a patented arrangement (3) in which the body bolster and bogie bolster are mechanically linked together has been introduced. The fittings, whilst opposing any tendency to relative motion in the transverse di-

(2) Probably as early as 1906.

(3) See note in the *Bulletin of the International Railway Congress Association*, July 1934, p. 755 : « New design of carriage bogie on the J. G. Brill system ».

rection, thanks to a damping device, leave the two bolsters complete freedom to move relatively to one another in the vertical plane. The combination of these two devices gives particularly interesting results.

[621. 43 (.43)]

The Deutsche Reichsbahn railcars with self-contained power plant,

by Herr BREUER, Reichsbahnoberrat, Berlin.

(Zeitschrift des Vereines Deutscher Ingenieure — V. D. I.)

Purchasing programme.

The annual programme of rolling stock to be purchased by the Reichsbahn for the following year is drawn up a few months before the end of each year. Once the credits have been voted it is most desirable that the reconstruction of the stock should be put in hand at once. The commencement of this work is dependent too on the amount of work the builders have in hand, and in the case of new designs or considerably altered designs, it also depends on the technical work involved in getting out the designs and completing the many drawings needed.

During the year the main programme is sometimes completed so as to cover any period during which the works are not very busy, or to give them some additional work. Then too, owing to altered conditions, certain vehicles provided for in the programme are not built or are replaced by different types.

The construction of the railcars, including trials and reception tests and the adjustments frequently needed, requires about a year if everything goes normally; however, in the case of new and complicated types, two years and more are required. The result is that the information published in the daily press about the purchasing programmes is given a long time before the latter are completed; sometimes furthermore, particulars of the orders placed are also given and possibly at the same time new railcars which have been shown on the programme for two years and more are reported as having been put into service. Erroneous ideas are formed and are made worse by the incomplete or incorrect description given of the different types of railcars. All information about new railcars should make it clear, therefore, whether it is a proposal for future use, or the actual putting into service of completed vehicles.

Table 1 gives the self-contained railcars to be built to the 1933 and 1934 and supplementary programmes corrected to date. When two numbers are shown opposite a main type in the column giving the number of such vehicles, different types of construction differing in important details are indicated.

The 1935 orders include, in particular, fast high-capacity railcars for a maximum speed of 160 km. (100 miles) an hour. These units, composed of three vehicles, which can be coupled together to give longer trains, will be allotted to long-distance services on the main lines. Other express railcars limited to speeds of 120 to 130 km. (75 to 80.8 miles) an hour will be worked more especially in the Ruhr where, owing to the number of large towns in a small area, the conditions are quite different. It would be premature to publish particulars of the number and type of these railcars.

TABLE 1. — **New types of railcar.**

Number of wheels.	Engines.		Type of engine and transmission.	Maximum speed.		Number ordered.		
	Number.	Horse-power.		Km./h.	M. p. h.	Full programme 1933.	Principal programme 1934.	Supplementary programme 1934.
4	1 1	135 or . . 150 . . .	Diesel mechanical.	75	46.6	10 14	15 + 1*)	—
4	1	150 . . .	Diesel hydraulic.	75	46 6	2	1**)	—
4	1	150/210 (†) .	Diesel hydraulic.	75	46 6	—	3	—
8	1	210 . . .	Diesel mechanical.	80	50	19	15 +13	—
8	1	210/280 (†) .	Diesel hydraulic.	80	50	—	2	—
8	1	300 . . .	Diesel electric.	90	56	3	6 + 4	—
8	2	150 . . .	Steam (Doble).	110	68.3	—	5	—
8	1	410 . . .	Diesel electric.	110	68.3	16 + 1	22 +14	60
8	1	420 . . .	Diesel hydraulic.	110	68.3	—	2	—
8	1	560 (†) . .	Diesel electric.	120 (130)	75 (80.8)	2	2	—
12	2	410 . . .	Diesel electric.	160	100	—	4	9
16	2	600 (†) . .	Diesel hydraulic.	160	100	—	2 + 1***)	—
16	2	600 (†) . .	Diesel electric.	160	100	—	—	2
					Total :	67	112	71

Miscellaneous information.

The purchase of railcars in rapidly increasing numbers, dimensions, and power has made it necessary to *widen the sources of supply*. Quite apart from designing more powerful machines, enquiries had also to be sent to various builders, for cars of the same power, and this greatly influences the form of construction. The result has been a considerable multiplication of the types.

Besides the *engines* used up to 1933, the new designs given in table 2 have been perfected, and several have developed much greater power by means of supercharging.

In addition to the mechanical *transmission* in use prior to 1933 the mecha-

(†) Supercharged engines.
(*) Maybach transmission with six-speed gear.
(**) Special wheels (Austro-Daimler).
(***) *Kruckenberg* design.

nical and hydraulic transmissions given in table 3 have been designed.

The following *electrical transmissions* are now in use :

System.	*Maker.*
M. S. W. (Leonard) . . .	Maffei Schwartzkopff.
B. B. C.	Brown-Boveri & Co.
Gebus	Siemens-Schuckert Werke (S. S. W.).
Lemp	Allgemeine Elektrizitäts-Gesellschaft (A.E.G.).
R. Z. M.	S. S. W., A. E. G., B. B. C.

TABLE 2. — **New designs of engines for railcars.**

Nominal horse-power.	Design.			Remarks.	Maker.
	Cycle.	No. of cylinders.	Cylinder arrange-ment.		
150	4 str.	6	In line.		M. A. N.
210	4 —	6	»	like the above but supercharged.	»
210	4 —	6	In line.		Maybach.
210	2 —	18	6-star.		Michel Motoren G. m. b. H.
210	4 —	6	In line.		M. A. N.
280	4 —	6	»	like the above but supercharged.	»
300	4 —	6	In line.		Motoren-Werke, Mannheim.
300	4 —	12	V		Daimler-Benz.
410	4 —	12	»		Maybach.
420	4 —	12	»		M.A.N. (double crank axle).
450	4 —	12	»		Daimler-Benz.
560	4 —	12		like the 420-H.P. but supercharged.	M. A. N.
600	4 —	—		supercharged.	Maybach.

Some horizontal engines are being designed, also a 12-cylinder 4-stroke engine, by Deutz.

TABLE 3. — **New railcar transmissions.**

Mechanical transmissions.

Horse-power.	Number of speeds.	Maker.
150	4	Triebwagenbau, A.-G. (TAG, Deutsche Werke).
150	4	Mylius (Deutsche Getriebe G. m. b. H.).
210	4	Maybach (with hydraulic coupling).
210	4	TAG (Deutsche Werke).
300	4	» » »
300	4	Mylius (Deutsche Getriebe G. m. b. H.).
135	6	Maybach.

Hydraulic transmissions.

Horse-power.	System.	Maker.
150	Trilok.	Klein, Schanzlin & Becker.
200	Voith. Torque converter and coupling.	Voith.
300	Voith. Torque converter and coupling.	»
400	Voith. Torque converter and coupling.	»
600	Voith and TAG. Two converters and reversing gear.	Voith and Deutsche Werke.

The R. Z. M. is the standard electrical transmission on all recent railcars subsequent to the main 1934 programme.

Whilst a certain degree of finality has been reached here — so far as finality is possible in technical matters — the engines and transmissions are still being improved. So far the electrical transmission has been the only one used for high powers. It is now subject to the competition of the hydraulic transmission, which is full of promise and, like it, gives a continuous transmission of the power and a sufficiently increased starting torque, besides which it can be built in a much lighter form.

Recently too, more interest has been taken in *automatically-stoked high-pressure steam railcars*, the engines of which drive the axles directly, without any complicated transmission. For fuel, cheap indigeneous oils (lignite tar oil and possibly oil from coal) can be used in these railcars rather than in diesel engines.

Also as regards *brakes*, several new types have recently been brought out, chiefly because of the altered conditions due to the much higher speeds. Amongst these it will be sufficient to mention the drum brakes, the disc brakes, and the electro-magnetic rail brakes.

To meet the public demand for greater *comfort*, the recent railcars are provided with more comfortable seats through the compartments being made wider. Wider lights too have been provided.

Most modern railcars have been built in such a way that two or three units consisting of motor and control vehicles can be coupled together, to form trains which can be driven as a whole unit, which condition has a considerable influence on the arrangement of the draw and buffing gear, on the brakes, and body work, and on the control gear.

Certain classes of vehicles are fitted with a new *ventilating* and *heating* system. Fresh air is forced into the vehicle by electric fans, the air in winter being heated by appropriate means : the heat is partly taken from the engine cooling water and partly from an oil-fired boiler. Unfortunately, most of the improvements introduced to increase the passengers' comfort also increase the weight and cost of the equipment.

The main types of railcar given in table 1 are divided into a much greater number of sub-types as the result of the various mechanical appliances added to them as described above, and the *changes* in the construction of the vehicles. This is necessary, however, for experimental purposes and for comparing the different solutions proposed,

so as to arrive at the best design as quickly as possible.

The Deutsche Reichsbahn is carrying out this important pioneer work not only in its own interests, but still more in the interest of the engine and carriage building industries, as it increases their productive capacity and gives them the possibility of exporting manufactured products of great intrinsic value.

In order to serve the country as a whole, the Reichsbahn has deliberately accepted the burden of the working difficulties resulting from such rapid development, such as the multiplication of designs put forward, the high first cost and expensive maintenance of the railcars, the difficulty of training the staff and the troubles involved in organising a spare parts service.

MISCELLANEOUS INFORMATION.

[621. 134.1 (.44)]

1. — The crank axles used on the Paris-Lyons-Mediterranean Company's 4-8-2 class A locomotives,

by Mr. CHAN,
Mechanical Engineer, Paris-Lyons-Mediterranean Railways.

(*Revue Générale des Chemins de fer.*)

Short note on the investigations which resulted in the Paris-Lyons-Mediterranean using a new type of 7-piece built-up crank axle on its 4-8-2 class A locomotives.

The crank axle of compound locomotives with inside cylinders is rather fragile and has caused much trouble. The more powerful locomotives become the more difficult it is to design, within the practically fixed space between the frames, a satisfactory crank axle.

For this reason, and because of the unsatisfactory behaviour of their crank axles in service, most railways have had to investigate the question with a view to finding the best

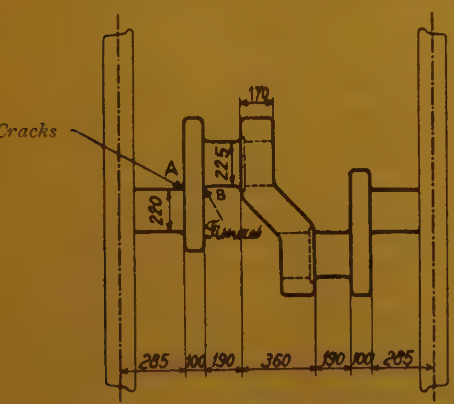


Fig. 1.

design for such crank axles. Some railways favour the solid crank axle, whilst others prefer the built-up type.

Instead of going into details about the various designs of crank axle in use, we feel it will be of greater interest to give briefly the reasons which led the Paris-Lyons-Mediterranean Company to use the present type of built-up crank shaft.

The low-pressure cylinders of the 4-8-2 class A Paris-Lyons-Mediterranean engines — particulars of which were given by Mr. Vallantin, the Chief Mechanical Engineer of the Company, in the February 1926 number of the *Revue Générale des Chemins de fer*, owing to their large diameter (720 mm. = 28 3/8 inches) had to be placed outside the frames.

This meant that the crank axle, driven by the inside high-pressure cylinders, had to transmit most of the power of the engine, as these cylinders developed some 2/3 of the total power. Thus, at a speed of 80 km. (50 miles) an hour, 1 800 H.P. is transmitted to the crank axle.

Already when these locomotives were being designed, and in view of the high power, the crank axle was made the second of the coupled axles so as to relieve it of the guiding forces, but even so the forces to be dealt with were considerable and made the design of a satisfactory crank axle difficult (1).

The original crank axle fitted in 1925 was built up of *three parts* (fig. 1). Each end portion, consisting of a journal, web and

(1) The following are some of the data used in the calculations :

— Boiler pressure : 16 kgr./cm² (227.6 lb. per sq. inch.) — receiver pressure : 3 to 4 kgr./cm² (42.7 to 56.9 lb. per sq. inch.).

— H.P. cylinder : bore : 510 mm. (20 1/16 inches) — stroke : 650 mm. (25 5/8 inches).

— Wheel diameter : 1.790 m. (5 ft. 10 15/32 in.).

Weight of one h. p. piston, piston rod, crosshead and connecting rod : 615 kgr. (1 356 lb.).

crank pin, was a single-piece forging. The manufacturers considered such a forging difficult to make satisfactorily, owing to the two projections for the crank pin and journal having to be forged one on each side of the flat bloom. Cracks might develop at the points where forging tended to open the metal, i.e. at the radii with the web. It was felt, however, that such a three-piece crank shaft should be built as it would be light and straightforward.

Figure 2 is a photograph of this axle.

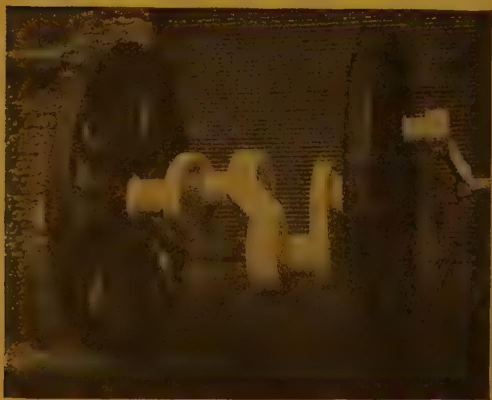


Fig. 2.

The axle was not satisfactory in service, however. After running a very short distance, some 50 000 km. (31 000 miles), cracks developed at the junctions of the crank pin and the journal with the web, precisely at the forged radii A and B of figure 1. Most of these cracks developed at A.

An attempt was made to prevent these cracks by reducing the stresses in the metal through balancing the axle in itself, that is to say by balancing each revolving mass by a counterbalance weight in its plane (see crank webs of figure 3). As the centrifugal forces due to the revolving masses no longer cause the axle to bend, the total stress is reduced.

At the same time that the webs were balanced, the journals were pressed in and this reduced the size of the forged connecting piece. The result was the five-piece built up crank axle of figure 3.

This axle stood up better than the previous one. The engine ran better and there was less heating trouble, possibly due to the crank being self-balanced. The cracks which still developed at B (fig. 3) were shallower

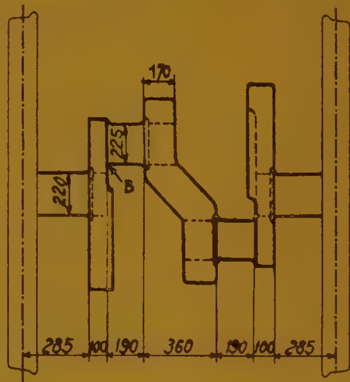


Fig. 3.

and developed more slowly, the distance run before discarding the axle reaching about 100 000 km. (62 000 miles). This, however, was still not good enough. Then too there was some tendency for play to develop between the parts of an axle after running some 100 000 km, this pointing to too thin webs (100 mm. = 3 15/16 inches) to maintain the press fit.

As the tendency to develop cracks was the worst defect, the Paris-Lyons-Mediterranean Railways then considered the use of built-up crank axles without a single forging. This meant that the webs must exceed 100 mm. (3 15/16 inches) thickness to give sufficient bearing for the journal shaft to be pressed in, the centre part of the crank being thick enough in the former design.

The crank web could only be made thicker at the cost of the journal or crank pins, that is to say with increased danger of overheating. If the design was to be pursued on these lines, the method of lubrication would have to be much improved.

The Paris-Lyons-Mediterranean Company

then introduced brasses fitted with felt pads soaked in oil, as used on different railways, and in particular on the French Nord and the English Railways [1].

It then became possible to reduce the length of the crank pin from 190 mm. to 140 mm. (from 7 1/2 to 5 1/2 inches), *or by 28 %* without any trouble in service. This considerable reduction allowed of the crank webs being increased to 125 mm. (5 5/64 inches), and a thoroughly reliable crank axle got thereby.

The built-up seven-piece axle, now being

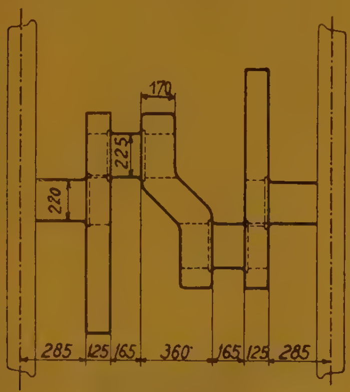


Fig. 4.

used and shown in figure 4, was designed on these lines; figure 5 is a photograph of it.

So as to be able to use up the centre part of the earlier axles, the length of the crank pins was not reduced to 140 mm. (5 1/2 inches); the length was reduced only on the side of that web the thickness of which it was necessary to increase. The centre line of the connecting rod in consequence does not pass through that of the crank pin, but this does not matter.

The first seven-piece built-up crank axles were put into service in November 1933.

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[1] See article by Mr. Oudet in the June 1931 issue of the *Revue Générale des Chemins de fer.*

We feel already, without having had to wait for them to run long distances, that this design has solved the crank axle problem on the 4-8-2 class A engines of the Paris - Lyons - Mediterranean, this problem being merely to get a built-up crank axle with thick webs (125 mm. = 5 5/64 inches) which would not run hot, and this has been secured.

As a matter of information, the axles are pressed cold with a 1 in 333 shrinkage allowance, using little tallow. The complete axle is then immersed in a potash bath to remove all grease. This method has been entirely satisfactory, and comparative

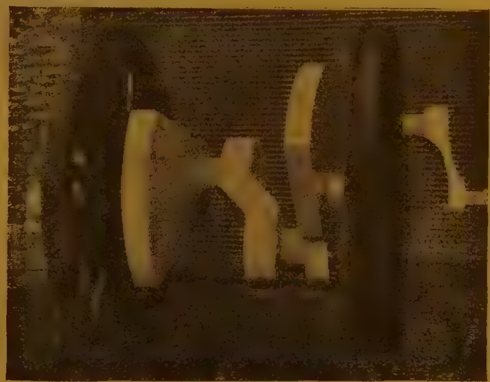

Fig. 5.

tests between cold and hot shrinking have shown one to be as good as the other.

To conclude, when discussing the best method of making crank axles, it can be stated that, it the solid forged crank axle has its partisans provided the quality of the metal is greatly improved, the built-up crank axle is in every way satisfactory when the bearings can be made as long as 125 mm. (5 5/64 inches) as in the case of the 4-8-2 class A locomotives of the Paris-Lyons-Mediterranean Railways.

[656. 256.3 (.44)]

2. — Automatic block with light signals, installed between Caen and Cherbourg,

by C. CHOUQUET, Ingénieur des Arts et Manufactures.
(From *Le Génie Civil.*)

The Caen-Cherbourg line is the first main line of the French State Railways to be equipped with the automatic block with light signals.

The details of this system were given in the *Génie Civil* of the 9th October, 1926.

The broad lines of the system are :

In an automatic block installation the si-

Fig. 1. — Automatic block system with light signals.
Equipment at the beginning of a section.

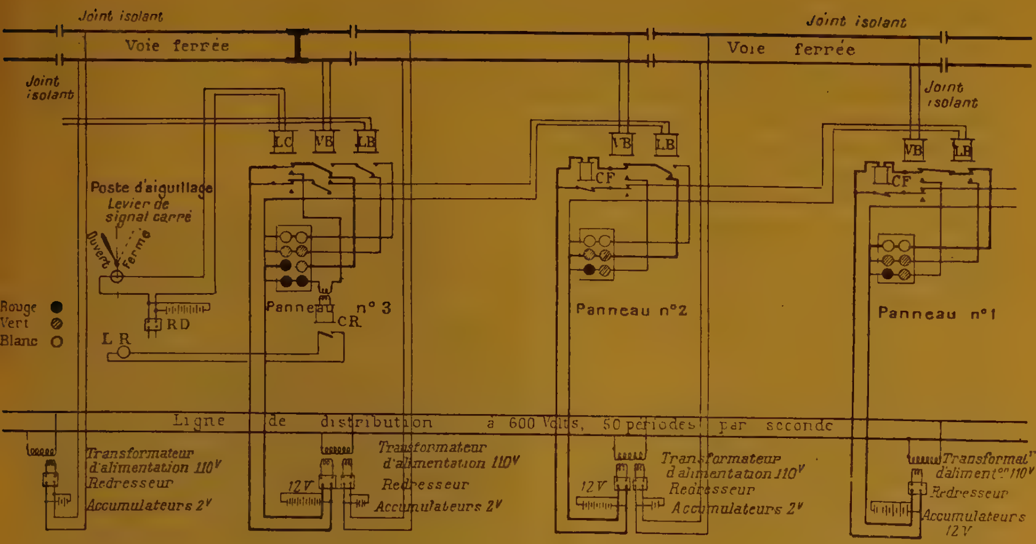

Fig. 2. — Diagram showing the current supply and control of the signal lights of an automatic block fed by rectified current.

Explanation of French terms:

Accumulateurs 2v = 2-volt accumulators. — Blanc = White. — Joint isolant = Insulating joint. — Levier de signal carré = Square signal lever. — Ligne de distribution... = Feeder line at 600 volts, 50 cycles. — Panneau = Panel. — Poste d'aiguillage = Signal box. — Redresseur = Rectifier. — Rouge = Red. — Transformateur... = 110-volt transformer. — Vert = Green. — Voie ferrée = Railway line.

gnals, which when « on » oppose the entry to occupied sections, are controlled — and held in the « on » position the whole time the section is occupied — by the trains themselves, without manual intervention.

To satisfy this condition, the automatic block with light signals uses alternating- or direct-current track circuits, the running rails acting as the conductors of the current.

The two lines of rails, interrupted at intervals by insulating joints form independent block lengths, each corresponding to the length of a block section. To one end of each section is connected a track relay which, being de-energised by the track being occupied, and energised when the track is clear, puts the block signal to « on » or « off » respectively. To the other end of the section is connected the electric power supply (transformer, rectifier, accumulator, primary battery, etc...).

The light indications given by an open line panel are of three sorts, each indication involving two lights :

a) the « semaphore » (stop), represented by a red and a green light shows that the section protected by the panel is *occupied*.

b) the « damier » (caution), represented by two green lights shows that the section is *clear* but the one ahead is *occupied*.

c) the « line clear » indication is given by two white lights.

The working of the open line panel is made clear by the simplified diagram (fig. 2) of the block system installed between Caen and Cherbourg.

When the track relay VB is de-energised by the occupation of the line, the semaphore (danger) lights (red and green) are shown. When the block section considered is clear, the track relay VB is energised. The panel

shows : either two greens when the block relay LB is de-energised, or two whites when this latter relay is energised. The block relay LB is controlled by the track relay VB ahead, and by the light control relay CF of the panel ahead. Thus the indication of the open ligne panel depends on the occupation of two succeeding block sections.

Finally the diagram indicates the control from a pointsman's post of the two red lights (square signal) with which panel No. 3 is fitted. In this case the block relay LB of the previous panel is also controlled by the block relay LC controlling the lights of the square signal in question.

The block equipment is fed with direct current supplied by rectifiers and accumulators fed in turn by alternating current supplied by six local supply companies, but mainly by the Caen Electricity Company.

The installation was installed by the Compagnie Générale de Signalisation, Paris. The Caen-Carentan section is already in service, and the Carentan-Cherbourg section will be by the end of the year.

The light panels have the signal lights now in use on the State Railways, but are so arranged as to be easily altered when the Verlant signalling is put into service. This Verlant system is the new signalling perfected by a Committee of the French Main-Line Companies, set up in 1926 under Mr. Verlant, Operating Superintendent of the Paris-Lyons-Mediterranean Railways. The principles of this signalling system have been dealt with in detail in the *Génie Civil* of the 28th February 1931, p. 216. One of the chief differences between the two systems is that the « line clear » indication will be given by a green light and no longer by a white light, while the « reduce speed » indication will be given by an orange light instead of a green.

The three-phase 220/125-volt 50-cycle alternating current is supplied at nine points, the end ones, of course, being Caen and Cherbourg. At each of these points, the voltage is stepped up to 600, and the alternating current is fed through a distribution feeder to the high-tension cupboards at the base of each light panel, where its voltage is reduced to 110.

The current is further stepped down to 12 volts in the relay locker of the panel, to feed the panel lights and the various block circuits, and to 2 volts only for supplying the isolated block zones and then rectified by Westinghouse dry rectifiers (1).

Each open line panel contains the lights for the semaphore (« stop »), « caution », and « line clear » aspects. It also has :

a) a detonator automatically exploded by the first pair of wheels passing the panel

Fig. 3. — View of the inside of a high-tension cupboard.

(time-locking bar) when this latter passes the semaphore at stop and provided there had not been any previous manual cancellation (this cancellation can only be made when the section ahead of the panel is occupied) ;

b) a ramp for repeating the signals on the

(1) This device was described in the *Génie Civil* of the 14th April 1928, p. 364. In the present installation, however, the rectifiers are self-regulating, and normally supply the current used, the accumulators merely acting as standby.

locomotive, which is only energised when the « caution » lights are shown;

c) a marker lamp which automatically takes the place of the panel when a lamp of any one of the lights has its filament broken.

Fig. 4. — View of the inside of a relay cupboard. The two rectifiers are placed in the top compartment.

In addition the block lights (« stop », « caution », « line clear ») are lighted during the occupation of one or the other of the two sections before the panel; this constitutes the approach lighting. The lights of the semaphore (« stop ») are lit if the first subsequent section is occupied; the lights of the « caution » aspect are seen if the second section beyond the panel is occupied.

Finally every light panel accidently extinguished is indicated back by the lights of the « caution » aspect being shown automatically on the preceding panel.

When a panel has the red lights of the square signal, these latter are controlled by the pointsman through a unit lever, fitted with the approach interlocking, and with the audible warning of discordant movements. Should any vehicle pass a light at danger a detonator at the panel is automatically exploded.

Figure 1, referring to an open line panel at the beginning of a block section, with six lights (one green and one red for the « stop », two green for « caution », and two white for « line clear ») makes it possible to appreciate the facility with which the present light signals can be changed into the Verlant system, the panel then only having to have three lights (one red for the « stop », one orange for « caution », and one green for « line clear »).

When introducing the Verlant signalling, it will be quite easy to do away with the left-hand tubular support with its three lights, as well as the rectangular screen plate, and to fit a circular screen plate with the three remaining lights.

This photograph shows from left to right the automatic detonator, the marker lamp, the relay cupboard and the high tension supply cupboard.

Figures 3 and 4 show : one, the interior of the high tension supply cupboard with its transformer, and the other, the inside of a relay locker in which, from top to bottom, will be seen the two rectifiers, the detonator relay, the relay controlling the lights, and the track and approach relays.

NEW BOOKS AND PUBLICATIONS.

[385 (.02]

The Universal Directory of Railway Officials and Railway Year Book, 1935/36. — London : The Directory Publishing Co. Ltd., 33, Tothill Street, Westminster, S. W. 1. — 1 vol. (8 1/2 × 5 1/2 in.) of 596 pages. (Price : 20 sh. net.)

The Universal Directory of Railway Officials, originally issued in 1895, reaches with the present volume its forty-first year of publication, and its third edition incorporating another old-established book of reference, The Railway Year Book, which completed its 35th year of publication in 1932.

The increasing development in the electrification of main-line steam railways has necessitated the complete overhaul of the tabulated statement of such changes, while the table of the world's total railway mileage, has been extensively revised in accordance with official replies to a new questionnaire. The remarkable safety of British railways is further exemplified by a new table summarising railway accidents and casualties in relation to passenger journeys, freight traffic, and staff, for the five-year periods 1920-24 and 1925-29, and for each of the years 1931-33 inclusive. A proportion of only 0.7 fatalities per million train miles was recorded in 1933.

British railway interests in road transport are shown in a financial table which covers both passenger and freight activities, and the list of omnibus interests and working arrangements has been retained and revised to date.

The lists of railway officials remain, brought up to date, together with brief descriptions of the chief railway systems of the world, and the latest available financial results. Besides the railway systems proper, information is given concerning governmental and other authorities exercising control over railways.

The general arrangement of the book is on a geographical basis, and the order in which they appear has been selected so as to group all the railways in the United Kingdom, British Colonial Empire and the Dominions in sequence, followed by the railways of foreign countries in which important British interests are held, and lastly, the railways of other foreign countries. Assistance in communicating with foreign railways is provided by a list in English, French, German and Spanish, of approximately comparable titles of officials. A further list shows London offices and agencies of their chief overseas railway administrations.

For ready reference purposes at the end of the volume will be found four indexes : 1) an index to countries; 2) an index to statistical and other information; 3) an index to railways etc.; 4) a personal index of railway officials.

In 1933 the amalgamation of the two old-established volumes resulted in the production of what is probably the most complete railway reference book ever compiled, and the additional features which have been incorporated in the 1935-1936 edition have still further increased the utility of the volume in directions which experience of the combined work has shown to be most desirable.

[608]

EICHENBERGER (E.). — **Amerikanische Erfinder** (*American inventors*): MORSE-BELL-EDISON. — One volume (8 1/4 × 5 1/2 inches) with many artistic engravings. — 1935, Berne, Kommissions-Verlag Hallwag. (Price : 3.50 Swiss francs.)

The work of the three great Americans, Morse, the father of the telegraph, Bell, the inventor of the telephone, and Edison the inventor of the phonograph, the incandescent electric lamp, and many other marvels, which have had such a marked influence on modern civilisation, is known but little or insufficiently.

The author describes the lives of the three inventors, the circumstances in which they were born and lived, the difficulties and obstacles they met and overcame by their tireless labour. The account is written in simple language, easily understood by everyone, and so is clear and pleasant to read.

Without going into technicalities, the book contains an accurate account understandable by the general public, of the inventions of Morse, Bell and especially Edison. The biographies with which the author begins are most interesting and full of teachings.

A review such as our *Bulletin* has good reason to mention this book. There are few inventions which do not affect railway operation. To mention the telegraph and telephone alone, can we imagine the railway working without them ?

The engravings must be mentioned separately. Thanks to the foresight of the automobile king, Henry Ford, the author was able to make use of a very rare collection of original photographs.

This work renders homage to three great men who have been the glory of America, as much by depicting their individual qualities and characters as by describing their inventions.

E. M.

[656 (.44)]

HAMACHER (W.), Doctor of Economics, delegate of the Touring Club of France. — **Die Neuordnung des Eisenbahnwesens und der Kraftwagenwettbewerb** in Frankreich. (*The new railway working conditions and road motor competition in France*). — One vol. (9 7/16 × 6 1/2 inches), of 124 pages, with tables, figures and inset plates. — 1935, Berlin, Deutsche Betriebswirte-Verlag, G. m. b. H., Postdamer Strasse, 108. (Price : 6 Rm.)

The author has carried out an enquiry into the position of the French railways and the repercussions which road competition has and can have on their management and organisation. The information he has collected has been obtained from official sources such as the managers of the railways, tourist organisations, publicists specialising in the subject, road operators, and motor manufacturers.

He seems to consider road transport as having advantages which make railways inferior to it in certain circumstances, but admits that the railway alone can meet the needs of the population for bulk transport over long distances.

The need for completing working agreements between the two forms of transport, taking into account the economics of each, he thinks has been shown, although, owing to the existing position this objective can only be reached by degrees.

The author begins his investigation by examining the railway position. He gives a historical review of the main-line companies and analyses the circumstances under which they were formed

and their development, with particulars of the agreements made between the State and the railways. Amongst these agreements that of 1921 may be considered as the railway statute. Analyses of the financial results from 1921 to 1934 are then given.

The second part is devoted to the rationalisation of transport in France. The author deals with all the recent reforms in the management and organisation of railways and then compares the railways with road transport. He brings out the various charges falling on them both and notes the results competition has had on the railways. He then considers the measures taken to obtain collaboration.

As the conclusion, the author presents a plan based on the amalgamation of all the main-line railways into a national railway of some 23 000 km. (143 000 miles). The rates structure of the « United State Railways » would be based on the principle of covering working costs. As regards road transport, this as a rule would be subject to administrative approval, in such a way that private initiative was not interfered with, and the rates would be supervised so as to be determined by the actual operating costs alone.

E. M.

[621. 132 3 (.44)]

CHAPELON (A.), Engineer, Locomotive Rolling Stock Department, Paris-Orléans — Midi Railways. — **Locomotives à grande vitesse à bogie et 4 essieux accouplés compound à 4 cylindres** à large circuit de vapeur, haute surchauffe et distribution par soupapes, provenant de la transformation des locomotives « Pacific » à roues motrices de 1.85 m. de diamètre, série 4501 à 4570 de la Compagnie d'Orléans. **(High-speed 4-8-0 four-cylinder compound locomotives with large-section steam passages, high superheat, and poppet valve gear, rebuilt from the Orléans Company's « *Pacific* » type locomotives with 6 ft. 13/16 in. diameter driving wheels, numbers 4501 to 4570).** — One volume 12 3/16 × 8 11/16 in.) of 160 pages with 6 plates and 86 figures. — 1935, Dunod, Publishers, 92, rue Bonaparte, Paris. (Price : 25 French francs.)

Amongst the attempts made in recent years to improve the Stephenson type of locomotive, with a boiler working at customary pressures and a reciprocating engine, that of the Paris-Orléans Railway, who rebuilt its 4500 class *Pacific* engines has been particularly noteworthy.

Mr. A. Chapelon, Engineer of the Company's locomotive and rolling stock department, has published a remarkable analysis of the tests the first altered engine underwent, and of the improvements demonstrated by these tests. Mr. Chapelon designed and perfected, on this engine, the blast pipe known by his name, which has appreciably increased the power of the locomotive.

Two articles were published on this subject in the February and March 1935 numbers of the *Revue Générale des Chemins de fer*, which Messrs. Dunod have now republished as a separate pamphlet.

The note begins by giving the principles on which the locomotive was altered, with a detailed description of the boiler and mechanism. It then gives the results obtained in running trials.

This part is followed by an investigation into the heat balance of the boiler and into the evolution of the steam in the engine.

The analysis of the indicated and drawbar horse-power, the comparisons between the results obtained in Germany and the United States, and the systematic investigation into the consumptions and efficiencies are developed with such care for detail that the article forms a very valuable collection of data for those

dealing with the locomotive technically.

Combustion questions, boiler production, heat efficiency and the working conditions of the boiler are all dealt with most fully.

The improvements introduced are such that, as the author points out, this 4-8-0 compound locomotive with a narrow grate of 3.76 m² (40.5 sq. feet) area, using very highly superheated steam, has developed 4 000 indicated, and 3 000 drawbar horse-power.

This work, as the above review shows, is a remarkable contribution to the study of recent improvements in the steam locomotive, and designers and builders will find much valuable information in its pages.

A. C.

[621. 135.4 & 625 215]

PORTER (S. R. M.), M. A., A. M. I. M. E., A. M. I. Loco. E. — **The mechanics of a locomotive on curved track.** — A pamphlet (11 3/4 × 9 inches) of 32 pages with 59 figures. 1935, *The Railway Gazette*, 33, Tothill Street, Westminster, London, S. W. 1.

The *Railway Gazette* has recently published in pamphlet form the important series of articles by the late Mr. Porter, on the behaviour of locomotives on curves, which had appeared previously in its pages.

The forces set up in the tyres and rails when a railway vehicle runs through curves at high speeds are very complicated, besides being of great importance to the railways, who are endeavouring to lengthen the life of their rails and tyres, and at the same time run at the highest speeds compatible with safety.

Many authors have written on this problem since the first investigations made by Mackenzie about 1884, amongst whom we may mention Von Helmholtz, Boedeker, Carter, Uebelacker whose theory of the centre of friction was epoch-making, and more recently Heumann and Baumann. Mr. Porter's paper, which gained the George Stephenson prize of the Institution of Mechanical Engineers, forms a continuation to Uebelacker's work and is in some way the conclusion thereof.

Mr. Porter's article is original in that the author shows that the forces set up by the wheel flanges of a locomotive against the rails when running through curves can be calculated by ordinary mechanics with sufficient accuracy if the coefficients of friction are taken as known. The author suggests how these coefficients can be calculated and reviews the investigations carried out in this connection on the Continent. He also demonstrates that the locomotive can be likened to a series of trucks defined as a number of pairs of wheels rigidly held in a frame, articulated with one another. The fundamental equations of dynamics can be applied to each truck to calculate the forces acting on the wheel flanges.

As the friction set up on the rolling circle is not known accurately enough, two theories have been considered: (1) that of simple slip of the tyre on the rail, generally accepted in Germany, and (2) that of a more complex motion, like that of a belt on a pulley, due primarily to the elastic deformation of the materials of the tyre and rail when in contact, suggested in England by Carter.

Examples based on the two theories are given in an appendix as are the graphical methods, in particular that of Heumann.

This article is a most valuable contribution to the study of the negotiation of curves by railway vehicles, and its conclusions will be of the greatest use when designing new locomotives or investigating the causes of derailments.

A. C.

[385. (06. 111]

OFFICIAL INFORMATION

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OF THE

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(¹) Retires at the 13th session.
(²) Retires at the 14th session.
(³) Retires at the 15th session.
(*) Died September, 1935.

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H. E. Ibrahim Fahmy **Kerim** Pasha (already named);

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U. **Lamalle** (already named);

R. **Le Besnerais** (already named);

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(2) Retires at the 14th session.
(3) Retires at the 15th session.

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E. **Mugniot** [3], directeur général de la Compagnie des Chemins de fer de Paris à Lyon et à la Méditerranée; 88, rue St-Lazare, Paris (9e);

H. E. Mohamed **Osman** Bey [3], under secretary of State, Egyptian Ministry of Communications; Cairo;

G. **Philippe** (*), inspecteur général des lignes Nord belges; Liége;

C. **Ramallo** [2], ingénieur, director del Instituto de Economia de los Transportes, Facultad Nacional de Ciencias Económicas; Buenos Ayres;

Dr. W. **Rauscher** [2], conseiller ministériel, directeur commercial des Chemins de fer fédéraux autrichiens; Vienna;

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(1) Retires at the 13th session.
(2) Retires at the 14th session.
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(*) Died August, 1935.

L. **Velani** (1), directeur général des Chemins de fer de l'Etat italien; Villa Patrizi, Rome;

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N... (2) (Germany);

N... (3) (Germany).

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SECRETARY'S OFFICE : 74, rue du Progrès, Brussels.

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E. **Minsart**, ingénieur principal à la Société Nationale des Chemins de fer belges;

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(1) Retires at the 13th session.
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